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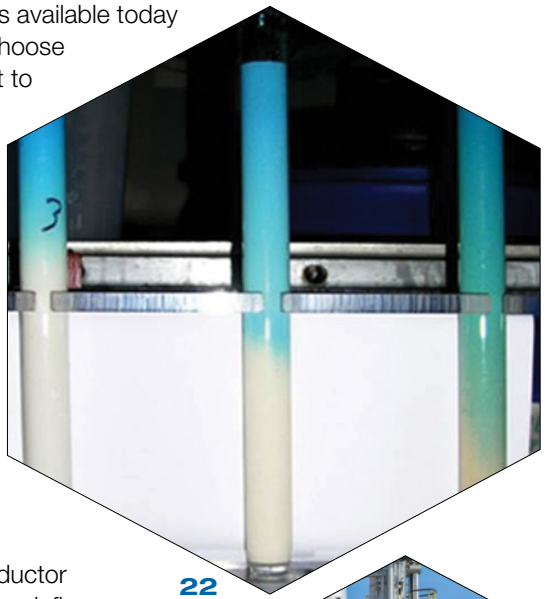
In the News

Technical and Practical



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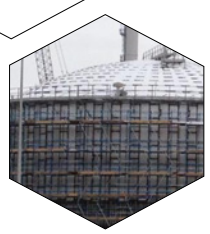

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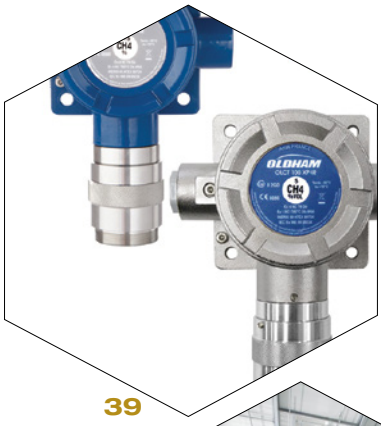

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Editor's Page

Regulating air emissions

There have been several recent announcements regarding regulatory changes that affect the chemical process industries (CPI). One of the latest is a set of final rules announced on April 9 by the U.S. Environmental Protection Agency (EPA; www.epa.gov) that significantly limits emissions of air pollutants from chemical manufacturing facilities. The main compounds targeted are ethylene oxide (EtO) emissions from synthetic organic chemical production and chloroprene emissions from neoprene manufacture. Describing these chemicals as "air toxics," the EPA points out that these two chemicals can have serious health effects in small quantities, and the new rule is expected to reduce related cancer risks in communities near facilities that emit them. According to the EPA, the rule will reduce emissions of these two compounds by nearly 80%.

In an earlier announcement on March 14, the EPA had disclosed its final rule specifically for EtO commercial sterilization facilities, which was aimed at reducing EtO emissions from those facilities by 90%.

Rule to reduce toxic air emissions

One of the requirements in the "Final Rule to Strengthen Standards for Synthetic Organic Chemical Plants and Polymers and Resins Plants" relates to improving the efficiency of flares that are used to control pollution. The EPA states that it is also finalizing stronger standards for heat exchangers, process vents and storage vessels. Emission-control exemptions from startup and shutdown operations are being eliminated.

The rule further requires fenceline monitoring of six compounds. In addition to EtO and chloroprene, the compounds include benzene, 1,3-butadiene, ethylene dichloride and vinyl chloride. The EPA cites that this type of monitoring has been very effective in identifying and reducing benzene emissions at petroleum refineries. "Action levels" that will prompt corrective action from the owners and operators have been defined for the monitored chemicals. Fenceline monitoring for chloroprene is required to begin 90 days after the rule goes into effect. There is a two-year deadline for monitoring of the other five chemicals.

The EPA did make adjustments to the proposed rule based on consideration of public comments. For example, EtO flare limit loads were not included, and emissions control levels for chloroprene from process vents and storage tanks were revised.

The American Chemistry Council (ACC; www.americanchemistry.com) responded to the release of the final rule with a statement that stated in part: "We are reviewing the details of this final rule as well as its impacts on vital industries across the country. This rule will have significant implications on the production of key chemistries such as ethylene oxide, which supports national priorities like electric vehicle battery development, domestic semiconductor manufacturing, and healthcare access." The ACC raised several concerns over the rule, including the toxicity value for ethylene oxide that was used by the EPA. Full details of the EPA's final rule and the ACC's statement can be found on their respective websites.

Update to recent SEC rule

Last month's column discussed a final ruling by the U.S. Securities and Exchange Commission (SEC; www.sec.gov) regarding reporting of climate-related risks. At the time of this writing, implementation of that rule has been paused, pending the outcome of legal challenges. ■

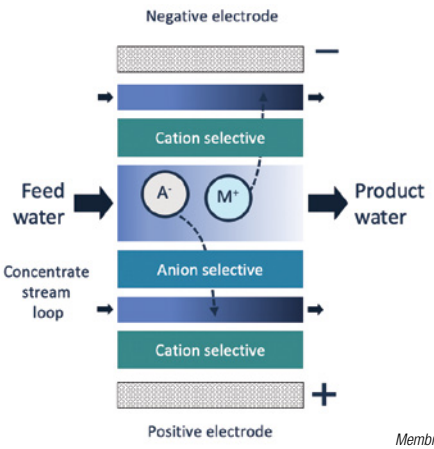
Dorothy Lozowski, Editorial Director

Edited by:
Gerald Ondrey

A new manufacturing approach for heavy-duty ceramic membranes

Membranes are widely used in a variety of industrial separation processes, but the polymeric materials that make up many membranes are not durable enough to handle extreme conditions, such as processes with low pH or hazardous-metal content. Membrion, Inc. (Seattle, Wash.; www.membrion.com) has developed the Electro-Ceramic Desalination (ECD) process, which uses ceramic membranes for ion separation in extreme environments where polymeric membranes would typically fail. "Ceramic membranes have been in use for decades, but they usually cannot be made with small enough pores to be suitable for ion-transport applications," explains Greg Newbloom, CEO of Membrion. Taking inspiration from the silica gel packs that are used to remove moisture from packaged foods, and which feature the tiny pores required for molecular transport, the team developed a unique way to shape the silica into membrane sheets instead of spheres. "We work in an amorphous phase with silica, using a sol-gel process to convert liquid materials into gel and then dry them into a solid, which we can then feed into a roll-to-roll process. No one else has really done roll-to-roll manufacturing with ceramics in this way before," says Newbloom. The company currently operates a pilot membrane-manufacturing facility in Seattle.

Another differentiator in the ECD process is the use of an electric field, rather than pressure, to drive the migration of ions. "The ECD assembly actually consists of two membranes — one selective for cations and one for anions. The electric field helps these ions move across the membrane, and they are then recombined in a concentrated stream. What's unique about our process is that it targets only ionically charged components," adds Newbloom. This makes it useful for treating wastewater streams with metal content and high acidity, such as those found in semiconductor manufacturing, which typically would require several separate treatment steps. "The technologies that ECD can replace are not typical membrane units — they're things like chemical precipitation, or thermal evaporation. In many cases, the most common thing that ECD can replace is simply a facility trucking wastewater offsite and disposing of it elsewhere," says Newbloom.



Membrion

Functionalized ceramic particles allow for heat-rejecting coatings

NanoTech Materials Inc. (Houston; www.nanotechmaterials.com) is expanding its commercial partnerships for the use the company's Insulative Ceramic Particle (ICP) technology, which can be used in fireproof coatings, as well as in a range of applications for roof coatings that lower cooling energy demands in large buildings. The company recently announced an arrangement with the California Department of Transportation (CalTrans) for using ICP in fireproofing wood structures to protect against wildfire damage, and a partnership with telecommunications major AT&T for thermal insulation.

ICP technology is based on an amorphous silica core that is functionalized with several nanoscale components that, together, give rise to its heat-rejection ability. ICP is synthesized as a powder with particle sizes of 4–30 µm using a proprietary process developed by NanoTech Materials. Company co-founder and CEO Mike Francis says the thermal conductivity coefficient (*k*-value) of the ICP powder is 0.017 W/mK, which minimizes heat transfer when the ICP is integrated into coatings, resins and building materials.

"The ICP combines perfect emissivity with low thermal conductivity to lower heat transfer and enhance solar reflectance index (SRI)," Francis says. In roof-coating applications, the ICP is added to a polymeric protective coating that is applied to building roofs at a thickness of about 1 mm. The coating rejects heat, allowing 20–50% reductions in cooling costs, depending on the nature of the building, Francis says.

In fireproofing applications, the ICP is applied as part of a resin matrix at a thickness of 5 mm. Upon exposure to high heat and flame, the resin burns away and the ICP undergoes a sintering process that protects the underlying substrate from flame damage.

RO MEMBRANES

Toray Industries, Inc. (Tokyo, Japan; www.toray.com) has developed a highly durable reverse osmosis (RO) membrane that is said to offer double the resistance to cleaning chemicals of conventional counterparts. This reduces performance degradation from membrane wear and simplifies operational management, halving replacement frequencies and shrinking the product's carbon footprint, the company says.

The company is preparing to mass produce this membrane and launch it in the rapidly expanding Chinese market in the first half of 2024, and aims to develop products with the new membrane for the global market.

Toray combined a scanning transmission electron-microscopy technology (developed at the Toray Research Center) and a digital data-analysis technique to quantitatively analyze the pores of the separation layer of RO membranes. Using this information, the company identified a substructure that helps enhance pore structure stability when in contact with cleaning chemicals. A manufacturing process was developed to design a new polymer structure, thus creating an RO membrane that delivers a stable pore structure.

PRUSSIAN WHITE

Sodium-ion batteries have many advantages over conventional lithium-ion batteries. Because they

(Continues on p. 6)

do not contain any critical resources, like lithium or cobalt, sodium-ion batteries promise to reduce costs of stationary energy-storage systems and electric mobility. So far, however, energy-storage materials required for production have been lacking. This situation is about to change, as Litona GmbH (Karlsruhe, Germany; litona-batteries.de) — a startup established at the Karlsruhe Institute of Technology (KIT; www.kit.edu) — plans to produce these materials on an industrial scale.

The startup company, founded by Sebastian Büchele from KIT's Institute for Applied Materials, is focusing on the Prussian white, which composed of mainly Na, Fe and Mn. "This energy-storage material can be used at the cathode of a sodium-ion battery," he says.

When researching sodium-ion technology, Büchele decided to synthesize Prussian white on his own. This work at KIT not only resulted in a high-quality cathode material, but also in a process to produce the material. To serve a bigger market, he founded Litona together with chemist Tom Bötticher. "Our competitors had problems in scaling the production of Prussian white analogs," Büchele says. "We think that we have solved these problems."

DRUG DISCOVERY

Last month, the life-science group Sartorius AG (Göttingen, Germany; www.sartorius.com)

(Continues on p. 8)

A faster way to manufacture bipolar plates

Bipolar plates (BPPs) are a key component in electrolyzers and fuel cells. BPPs include two key components: the membrane electrode assembly (MEA), in a fuel-cell system; and the catalyst-coated membrane (CCM), in an electrolyzer. In a fuel-cell stack, for example, the double-walled structure of the BPPs allows oxygen and hydrogen to flow to both sides of the MEA while water cools the stack. The problem is that the current process of producing BPPs is expensive, making widespread adoption of fuel cells uneconomical.

Now, researchers at the Fraunhofer Institute for Machine Tools and Forming Technology (IWU; Chemnitz, Germany; www.iwu.fraunhofer.de), in partnership with Profiroll Technologies GmbH (Bad Düben, Germany; www.profiroll.de), have developed a prototype system for roll embossing, named BPPflexRoll, which makes it possible for continuous mass production, instead of the conventional batch-wise fabrication method.

In the newly developed technology, the structure of the BPP is embossed using a pair of rollers (photo), with the wafer-thin metal band running continuously between them. One of the forming rollers is defined as the punch, the other as the die. Since the rollers used to form the flow channels have approximately only one line contact with the workpiece, the step-by-step forming can reduce the process forces by a factor of ten on average compared to conventional embossing.

"One major advantage of roll embossing is the higher process speeds involved. As many as 120 BPP half plates can be produced every minute," notes Robin Kurth, group manager for forming machines at Fraunhofer IWU. The researchers hope that this shift in production methods will cut the costs of manufacturing BPPs in half.

A pilot-production line is already running at Fraunhofer IWU, and the first bipolar plates produced with the pilot facility are already being tested in fuel cells at the Fraunhofer Institute for Solar Energy Systems ISE in Freiburg. The Fraunhofer researchers presented one component of the system at the Hannover Messe last month (April 22–26).

Solid-state synthesis simplifies cathode manufacture

The production and processing of cathode active materials (CAM) are among the largest contributors to the cost of lithium-ion battery manufacturing. Typical CAM manufacture involves multiple, multiphase steps in a co-precipitation process that requires a large amount of water and creates a significant amount of solid sodium-sulfate waste. A new, all-solid-state CAM technology aims to lower costs and create less waste in CAM production. The single-step CAM-synthesis process developed by Sylvatex Inc. (Alameda, Calif.; www.sylvatex.com) requires no water, and is similar to a typical milling process. "Our goal is to use mixed hydroxide precipitate [MHP], containing both nickel and cobalt hydroxides, as raw material. Typically, the metal hydroxides in MHP must be converted to metal sulfates before CAM synthesis, but we can use the hydroxides themselves, so we're cutting out a key portion of the process costs," explains Joe Adiletta, vice president of battery commercialization at Sylvatex.

This process also simplifies CAM synthesis in that the lithium hydroxide can be added alongside the other metals. Also key to the Sylvatex technology is a proprietary solid additive that acts as a reaction facilitator amongst the metals. "Normally, the lithium must be added later in the process, necessitating multiple steps. The output of our milling process goes directly to calcination. Since the process is analogous to traditional milling, it can use commercial, off-the-shelf equipment, allowing this pathway to scale relatively quickly," comments Adiletta. Going into the calcination step, the process can take advantage of heat created by the exothermic reaction facilitated by the additive, essentially lowering the heating requirements.

Sylvatex has reported 25% lower costs for its CAM compared to conventional production methods, along with a 50% reduction in carbon footprint.

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and startup company TheWell Bioscience (North Brunswick, N.J.; www.thewellbio.com) agreed to partner on the further development of hydrogels and bioinks tailored to produce 3D advanced cell models for drug discovery workflows. In addition to this, Sartorius will expand the portfolio of its laboratory division by distributing TheWell Bioscience's products, and invest in a minority shareholding in the company.

TheWell Bioscience is a pioneer in the field of animal-free hydrogels and bioinks, critical components for the creation of 3D biomimicking platforms, also known as 3D cell models, for precision medicine, cell therapy and biomanufacturing. These models are complex biological structures that mimic the organization and function of cells in living organisms, enabling a more accurate prediction of the efficacy, toxicity and side effects of drugs in humans.

CNT FILMS

Last month, Canatu Oy (Vantaa, Finland; www.canatu.com) and Denso Corp. (Kariya, Japan;, www.denso.com) started up their new, jointly developed carbon nanotube (CNT) reactor at the Canatu factory in Finland. The new high-performance reactor was developed to scale-up CNT film manufacturing to meet increasing demand to address the global advanced driver-assistance systems (ADAS) market with more competitive products. Through this development, Canatu and Denso can triple the throughput of Canatu CNT films while maintaining record-high performance.

Through joint development, Canatu and Denso have significantly progressed in scaling and

(Continues on p. 9)

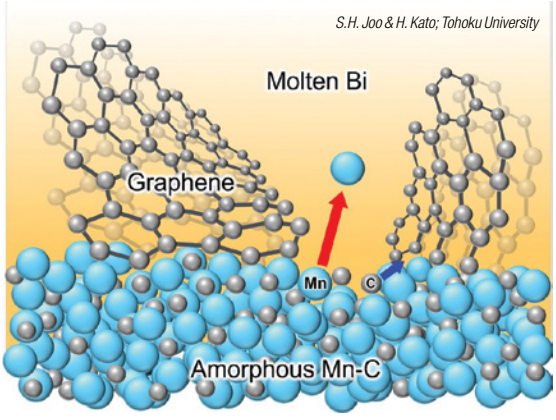
Improving sodium-ion batteries with nanocellular graphene

Nanocellular graphene (NCG) is a specialized form of graphene that achieves a large specific surface area by stacking multiple layers of graphene and controlling its internal structure with a nanoscale cellular morphology. Although the material has the potential to improve the performance of electronic devices, energy devices and sensors, its development has been stymied by defects that occur during the manufacturing process. Cracks often appear when forming NCG, and scientists are looking for new processing technologies that can fabricate homogeneous, crack-free and seamless NCGs at appropriate scales.

A promising new method that produced crack-free NCG has been reported by researchers at the Institute of Materials Research, Tohoku University (Japan; www.nem2.imr.tohoku.ac.jp) in a recent issue of *Advanced Materials*. The method uses a process known as dealloying, which exploits the varying miscibility of alloy components in a molten-metal bath. This process selectively corrodes certain components of the alloy while preserving others.

"We discovered that carbon atoms rapidly self-assemble into crack-free NCG during liquid metal dealloying of an amorphous manganese-carbon precursor in molten bismuth [diagram],**"** says Won-Young Park, a graduate student at Tohoku University.

Park and his colleagues demonstrated that NCGs developed by this method exhibited high tensile strength (34.8 MPa) and high electrical conductivity (1.6×10^4 S/m) after graphitization. Moreover, they put the material to the test in a sodium-ion battery (SIB). **"**We used the developed NCG as an active material and current collector in a SIB, where it demonstrated a high rate, long life and excellent deformation resistance,**"** says Park. **"**Ultimately, our method of making crack-free NCG will make it possible to raise the performance and flexibility of SIBs — an alternative technology to lithium-ion batteries for certain applications, particularly in large-scale energy storage and stationary power systems where cost, safety and sustainability considerations are paramount.**"**



Electrochemical sensor selectively detects dangerous bacteria

Researchers at Goethe University Frankfurt (www.uni-frankfurt.de) and Kiel University (both Germany; www.uni-kiel.de) have developed a new sensor for the detection of bacteria. It is based on a chip with a surface coating that ensures only very specific microorganisms, such as pathogens, adhere to the sensor.

The sensor makes use of the fact that microorganisms only ever attack certain body cells, which they recognize from the latter's specific sugar molecule structure. This matrix, known as the glycocalyx, differs depending on the type of cell.

"In our study, we wanted to detect a specific strain of the gut bacterium *Escherichia coli*," explains professor Andreas Terfort from the Institute of Inorganic and Analytical Chemistry at Goethe University Frankfurt. "We knew which cells the pathogen usually infects. We used this to coat our chip with an artificial glycocalyx that mimics the surface of these host cells. In this way, only bacteria from the targeted *E. coli* strain adhere to the sensor."

The study, published in *Applied Materials & Interfaces*, documents how effective the sensing technique is. The researchers mixed pathogens from the targeted *E. coli strain* among harmless *E. coli* bacteria in various concentrations. "Our sensor was able to detect the harmful microorganisms even in very small quantities," explains Terfort. "What's more, the higher the concentration of the targeted bacteria, the stronger the emitted signals."

The sensor is simpler to use than traditional methods, which are often time-consuming, require expensive equipment or can only be used by specialists. Moreover, they are often unable to distinguish between active bacteria and their decay products. A potential application is using the sensor in regions where there are no hospitals with sophisticated laboratory diagnostics, for example, or in bioreactors.

A next-generation membrane for durable fuel cells and electrolyzers

Hydrogen fuel cells and electrolyzers will be crucial technologies as the global energy transition progresses. However, both devices are often hampered by issues with durability and material costs — mainly associated with their membrane elements — which have slowed their widespread adoption. Now, a material-science breakthrough developed by Celadyne Technologies Inc. (Chicago, Ill.; www.celadynetech.com) has led to an alternative membrane technology called Dura, which is both more durable and efficient than the conventional proton-exchange membranes (PEMs) that are the heart of many fuel cells and electrolyzers.

"Current fuel cells struggle with durability because hydrogen crossover inadvertently causes side reactions that lead to degradation of the membrane, catalyst layer and other components. Dura is the first-ever low-permeability, bilayer PEM that is durable, chemically impermeable and conductive," says Gary Ong, CEO and founder of Celadyne Technologies. Creating such a membrane required marrying two very different materials into a composite that reduces gas permeation across the membrane while retaining high conductivity and stability to enable thinner membranes with overall lower membrane resistance. "We built upon developments in hydrocarbon chemistries that were developed for fuel cells while combining this understanding with how composites are made at the micro- and nano-meter scales.

"Dura cuts down on hydrogen crossover by more than 50% to address the root cause of free-radical formation in fuel cells while enhancing electrolyzer safety, especially at high pressures and low current densities," says Ong. Also, when compared to traditional PEM membranes, Dura's fabrication reduces the usage of per- and poly-fluoroalkyl substances (PFAS) by around 60%.

Celadyne Technologies has worked with the U.S. Air Force (Washington, D.C.; www.af.mil) to operate a demonstration-scale 100-W fuel cell, and the company is also collaborating with partners to explore the deployment of its technologies into heavy-duty trucking, wastewater treatment plants and other industrial applications.

Storing and processing anhydrous hydrogen chloride as an ionic liquid

Hydrogen chloride is an important byproduct of the chemical industry, with over 9-million ton/yr generated by industrial chlorination processes, such as the production of chloromethanes and polymers (polyurethanes and polycarbonates). Although HCl can be easily recovered by gas scrubbing with water to form hydrochloric acid, the HCl solution (typically 20%) is not suitable for many processes that require anhydrous HCl gas.

Now, an alternative approach is being developed by researchers at the Freie Universität Berlin (FU Berlin; Germany; www.bcp.fu-berlin.de), led by inorganic-chemistry professor Sebastian Hasenstab-Riedel, in collaboration with partners from the Technische Universität Berlin (www.tu.berlin). In the method, described in a recent issue of *Science Advances*, HCl is converted into an ionic liquid, which makes it easier and safer to store, handle and process anhydrous HCl.

The researchers discovered that HCl gas can be safely bound to the triethylmethylammonium chloride salt, $[N(C_2H_5)_3CH_3]Cl$, to create an ionic liquid, called bichloride, $[N(C_2H_5)_3CH_3][Cl(HCl)_n]$, under ambient conditions. HCl can then be safely released from this bichloride following transportation or storage.

Although HCl release is possible from this ionic liquid by heat or vacuum, the bichloride can be used directly to produce base chemicals, such as vinyl chloride, the chemists report. The study also showed that $[N(C_2H_5)_3CH_3][Cl(HCl)_n]$ can be electrolyzed under anhydrous conditions, using a membrane-free cell, to generate H_2 and the corresponding chlorination agent $[N(C_2H_5)_3CH_3][Cl(Cl_2)_n]$, enabling the combination of these ionic liquids for the production of base chemicals. ■

controlling the chemistry of Canatu's proprietary CNT-synthesis process. This enables large-scale production of CNT films with consistent quality for highly engineered applications.

Since 2015, Canatu has already been producing CNT film using its proprietary production process. "We have fine-tuned our own process to ensure consistent quality. With the new high-performance reactor, we will take a giant leap forward in industrial-scale carbon nanotube film manufacturing," says Taneli Juntunen, vice president of engineering at Canatu.

Key design changes included sizing up the reactor and its components and implementing a parallel-furnace design to multiply the synthesis process yield. Optimal CNT-growth conditions to maximize yield were realized through modular reactor prototypes and system-scale simulations. The new reactor cluster is equipped with *in-situ* monitoring of CNT growth, and a new collection chamber design.

CO_2 CAPTURE

Operational since April 2023 on ArcelorMittal's Dunkirk site, the industrial pilot plant for the capture of CO_2 present in blast-furnace gases has delivered promising results. The objective of this pilot is to validate the DMX capture process, developed by IFP Energies nouvelles (IFPEN; www.ifpenergiesnouvelles.fr) and marketed by Axens (both Rueil-Malmaison, France; www.axens.net). The industrial pilot was built and is being operated within the framework of two projects: the European H2020 "3D" project involving 11 European partners, and the DinamX project.

Results obtained since April 2023 are in line with expectations for the technology and confirm, even at this early stage, the efficiency and energy performance of DMX technology. A comprehensive series of operational tests has been conducted with the unit operating 24 h/d, 7 d/wk. The CO_2-capture rates exceed 90%, and the pilot unit produces CO_2 with a high level of purity (>99.5%) while energy consumption remains remarkably low, according to Axens. Moreover, after thousands of operational hours, no solvent degradation has been observed in spite of the high concentrations of contaminants present in the gas treated.

Developed and patented by IFPEN, the DMX process uses an amine demixing solvent to capture CO_2 contained in the fluegases produced by heavy industries (for more details and a process flowsheet, see *Chem. Eng.*, July 2019, p. 7). ❐

LINEUP

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Plant Watch

Celanese expands production capacities for acetic acid and VAE

April 9, 2024 — Celanese Corp. (Dallas, Tex.; www.celanese.com) started up a new production unit for vinyl acetate ethylene (VAE) in Nanjing, China and completed several downstream debottlenecking projects related to redispersible polymer powders (RDP). This new VAE unit increases capacity by 70,000 metric tons per year (m.t./yr). Celanese also started up a capacity expansion for acetic acid at its site in Clear Lake, Tex.

Shin-Etsu Chemical announces new plant for semiconductor lithography materials

April 9, 2024 — Shin-Etsu Chemical Co. (Tokyo, Japan; www.shinetsu.co.jp) is building a new plant to produce semiconductor lithography materials in Isesaki City, Japan. Investment in the site is expected to amount to about ¥83 billion (around $547 million) at the completion of the first phase of construction. The first phase of investment is to be completed by 2026.

Repsol begins large-scale production of renewable fuels in Cartagena

April 9, 2024 — Repsol S.A. (Madrid, Spain; www.repsol.com) began large-scale production of renewable fuels at its industrial complex in Cartagena, Spain. This plant is the first on the Iberian Peninsula dedicated exclusively to the production of 100% renewable fuels. The company has invested €250 million in the construction of the unit, which has a production capacity of 250,000 m.t./yr.

Innophos upgrades production facility for calcium phosphates

April 9, 2024 — Innophos, Inc. (Cranbury, N.J.; www.innophos.com) is investing in production upgrades at its facility in Chicago Heights, Ill., which produces calcium phosphates that comply with European Commission regulatory standards for purity. Calcium phosphates are ingredients in dietary supplements and many food and beverage products.

Borealis invests €4.5 million to upgrade olefins plant in Finland

April 9, 2024 — Borealis AG (Vienna, Austria; www.borealisgroup.com) plans to invest €4.5 million to upgrade the steam-cracker furnaces at its olefins unit in Porvoo, Finland. This investment enables Borealis to increase the share of renewable and recycled raw materials used in its ethylene and propylene production. The Porvoo investment program is expected to be completed in 2025. The Porvoo steam cracker has a nameplate capacity of 430,000 m.t./yr of ethylene and 263,000 m.t./yr of propylene.

Phillips 66 announces milestone in production of renewable diesel

April 5, 2024 — Phillips 66, Inc. (Houston; www.phillips66.com) announced that its Rodeo Renewable Energy Complex project in California has progressed, with the facility now processing exclusively renewable feedstocks and producing approximately 30,000 bbl/d of renewable diesel. The complex is on track to increase production rates to more than 50,000 bbl/d of renewable fuels by the end of the second quarter of 2024.

Archroma to expand manufacturing complex in South Carolina

April 5, 2024 — Archroma (Pratteln, Switzerland; www.archroma.com) is expanding its operations in Martin, S.C. The expansion will include a $750,000 investment in the facility and equipment, with additional growth anticipated. The facility specializes in the production of dyes, chemicals and optical brightening agents for textiles, packaging and paper, as well as coatings, adhesives and sealants.

BASF breaks ground on methyl glycols plant at Zhanjiang *Verbund* site in China

April 1, 2024 — BASF SE (Ludwigshafen, Germany; www.basf.com) has broken ground on a methyl glycols (MG) plant at its *Verbund* site in Zhanjiang, China. The new facility is designed with a capacity of 46,000 m.t./yr, and aims to meet the rapidly growing demand for brake fluids in the region. The plant is scheduled to commence operations by the end of 2025.

Ecolab opens wastewater-treatment plant at Shell Jurong Island in Singapore

March 29, 2024 — Ecolab, Inc. (St. Paul, Minn. www.ecolab.com) announced that its water-management division, Nalco Water, opened a wastewater-treatment plant at Shell Jurong Island, Singapore. This facility is designed to handle variable bio-treater wastewater. The plant utilizes Ecolab's ultrafiltration and reverse osmosis (RO) membrane system and is almost 100% automated. The plant has capacity to treat and reuse up to 24,000 m^3 of wastewater each month.

Eastman selects Longview, Texas as site for new molecular-recycling facility

March 28, 2024 — Eastman Chemical Co. (Kingsport, Tenn.; www.eastman.com) plans to build a second molecular-recycling facility at its location in Longview, Tex. The Longview molecular-recycling facility will have the capacity to recycle approximately 110,000 m.t./yr of hard-to-recycle plastic waste. The investment also includes operations that will prepare mixed plastic waste for processing.

Dow announces new production facility for carbonate solvents
March 27, 2024 — Dow, Inc. (Midland, Mich.; www.dow.com) plans to establish a new production facility for carbonate solvents on the U.S. Gulf Coast. The facility will use captured CO_2 from Dow's ethylene oxide manufacturing unit as feedstock for carbonate solvent production.

Mergers & Acquisitions

Sika acquires California-based polymer-systems specialist KBP
April 5, 2024 — Sika AG (Baar, Switzerland; www.sika.com) has acquired Kwik Bond Polymers, LLC (KBP; Benicia, Calif.), a manufacturer of polymer systems for the refurbishment of concrete infrastructure. KBP has production assets near San Francisco and additional production and warehousing near Pittsburgh, Pa.

SLB to acquire oilfield technologies firm ChampionX
April 2, 2024 — SLB (Houston; www.slb.com) agreed to acquire ChampionX Corp. (The Woodlands, Tex.; www.championx.com) in an all-stock transaction. ChampionX provides a wide range of chemical technologies for the oil-and-gas sector, and also offers technologies for emissions management, artificial lift, digital monitoring and more.

Dow and Procter & Gamble to develop a new recycling technology
April 1, 2024 — Dow and Procter & Gamble Co. (Cincinnati, Ohio; www.pg.com) agreed to jointly develop a new recycling technology that will enable conversion of hard-to-recycle plastic packaging into recycled polyethylene with near-virgin quality. The development program will focus on using dissolution technology to recycle a broad range of plastic materials with a focus on polyethylene and targeting post-household plastic waste — especially rigid, flexible and multilayer packaging.

Ineos acquires TotalEnergies assets in southern France
April 1, 2024 — Ineos Ltd. (London, U.K.; www.ineos.com) acquired TotalEnergies' (Paris, France; www.totalenergies.com) 50% share of selected petrochemicals assets located in Lavera, in southern France. Acquired business lines include: Naphtachimie (720,000-m.t./yr steam cracker); Appryl (300,000-m.t./yr polypropylene unit); Gexaro (270,000-m.t./yr aromatics unit); and 3TC (naphtha storage unit). These businesses had previously been joint ventures between the two companies. A number of other infrastructure assets have also been acquired, including part of TotalEnergies' ethylene pipeline network in France.

Talos Energy sells CCS business to TotalEnergies
March 19, 2024 — Talos Energy Inc. (Houston; www.talosenergy.com) entered into an agreement for the sale of its wholly owned subsidiary, Talos Low Carbon Solutions LLC (TLCS), to TotalEnergies E&P USA, Inc. for a purchase price totaling approximately $148 million. The sale includes Talos's entire carbon-capture and sequestration (CCS) business, including its three projects along the U.S. Gulf Coast: Bayou Bend CCS LLC, Harvest Bend CCS LLC and Coastal Bend CCS LLC. ■

Mary Page Bailey

Evolving Demand and Feed Profiles Challenge Refiners

Trends related to the energy transition are shifting global demand for refined products and affecting feedstock slates, forcing petroleum refiners to embrace adaptation and flexibility

Demand for fossil fuels has remained strong in the years after the COVID-19 pandemic, but the pressure for lowering greenhouse-gas (GHG) emissions also remains high. The momentum for an energy transition to low-carbon fuels and renewable energy is now sufficient enough that it will have a growing impact on demand for refined products into the future. Combined with other factors, such as geopolitical conflicts, natural disasters and government environmental policies, the push toward lowering CO_2 emissions requires petroleum refiners to build flexibility into their operations to adapt to changing demand profiles for products, and changing feedstock slates (Figure 1).

Significant opportunities exist for refiners to offset medium- and long-term declines in demand for traditional transportation fuels by changing their product portfolios to include more lower-carbon fuel alternatives, such as biofuels and hydrogen, and more chemical precursors. Between the rising demand for low-carbon fuels and the slowing, but still positive, demand for traditional fuels, petroleum refiners currently have a window of opportunity to position themselves for the future without disruption of financial stability.

"The most competitive refiners typically have at least one of the following advantages: cheap crude, captive product market, high complexity and conversion unit capacity, integration with petrochemicals, or strong logistics," explains Austin Lin, a principal analyst at Wood Mackenzie (Edinburgh, U.K.; www.woodmackenzie.com), so it is along these themes that refinery investment will likely occur. "Modernization and equipment upgrades [will be] targeted toward improving jet [fuel] and diesel yields (via a hydrocracker) given the higher margins and expectations of longer-lasting demand," Lin suggests.

"The industry has demonstrated a willingness to invest in new technologies and projects to decarbonize, but the economic incentive remains a key part of that transition," Lin says.

Comments from Shell Catalysts and Technologies (Shell C&T; Houston; www.shell.com) align with the idea of building flexibility and conversion capacity into refineries. "Flexibility will be key as refiners process a wider variety of feed sources and convert those to a more diverse product range," the company says, adding that refineries could see a move toward more specific molecule targets, rather than distillation ranges for fuels. "Building flexibility and efficiency around conversion assets will be critical to adapt to changing landscapes," Shell C&T says. This includes future work with non-conventional feeds, such as pyrolysis oils and recycled plastics.

"Petrochemical integration also remains a key trend, with many newer facilities and expansions in the Middle East and Asia aiming to maximize flexibility across the value chain," Wood Mackenzie's Lin says.


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FIGURE 1. Decarbonization goals and the need to adjust to changing product demand is prompting refiners to build flexibility into their operations

Refined products demand shift

Recent industry analyses have looked at the forecasted demand for transportation fuels in different regions. For example, a trend report from Deloitte Consulting (London, U.K.; www.deloitte.com) [*1*] projects global oil demand will slow down in the long term, rising annually by only 0.4 million bbl/d until 2027. Meanwhile, the report says global biofuels demand is projected to rise by 44% between 2022 and 2027, as it increasingly substitutes for petroleum-based products. In addition, the share of electric vehicles in global car sales is expected to range between 62% and 86% by 2030, according to research by RMI (Basalt, Colo.; www.rmi.org) [*2*]. Rising sales will be led by Northern Europe and China, and will be driven by policy, RMI says.

Wood Mackenzie's Lin says, "In the medium- to long-term view, European and North American markets are expected to see peak oil demand in the next few years, as vehicle electrification and policy changes outweigh normal growth. Meanwhile, the Asian market is expected to continue growing, with new refining capacity continuing to come online in the region."

"This shift will place rationalization

pressure on Western refiners as they look to increasingly compete in export markets, making the business case for reinvestment challenging for many facilities," Lin remarks.

Chris Jablonski, vice president of downstream technology at Chevron Corp. (San Ramon, Calif.; www.chevron.com) points out the unevenness of the demand changes. He says while Chevron sees oil and gas continuing to play a critical role in meeting global transportation demand for the foreseeable future, there are headwinds for gasoline, including electrification of the vehicle fleet. Thus far, however, the trends in electrification have generally met the company's expectations. "There will be certain times when [electrification] accelerates and other times when it slows down," Jablonski says, and "there are [geographic] areas where electrification will be widespread, and others where it will not."

Crude petroleum availability is also impacting refinery operations. "Crude slates remain a concern, particularly in Europe and Asia, where the combination of Russian sanctions and OPEC+ production cuts have reduced the availability of medium and heavy barrels in the market," Wood Mackenzie's Lin says. "The shift to lighter crude diets has challenged refiners from a yields perspective, which has been a contributing factor to high refined product crack spreads."

Renewable fuels

Growing demand for fuel products sourced from materials other than conventional crude petroleum is prompting refiners to increase production of renewable diesel and sustainable aviation fuel (SAF), but difficulties remain. "Renewable fuels are a hot topic in the industry right now, with significant capacity coming online in both North America and Europe in recent years," Lin says, "However, economics and feedstock availability remain a challenge for continued growth — currently, renewable fuels are not profitable to produce without significant policy support, with the feedstocks themselves being more expensive in many instances than the conventional fuels they are replacing."

Based on current differences among the regions in regulatory environment and stated carbon-emissions-reduction goals, Europe is expected to be a global hub for SAF, while the U.S. is expected to lead in renewable diesel, Lin says.

Looking ahead, he explains, "While current policies remain supportive for existing capacity, additional incentives may be needed to spur further investment, as producers are forced to consider lower-margin feedstocks due to availability issues. As a result, there is an expected ceiling for the renewable-fuels market, where additional capacity is uneconomic or politically challenged (for example, because of agricultural feedstock competition against food supply concerns)."


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FIGURE 2. Demand for renewable diesel and sustainable aviation fuel (SAF) is growing, but there are concerns over feedstock availability

The Deloitte report says, "Refiners may grapple with the task of effectively leveraging subsidies and grants for strengthening the biofuel supply chain. Therefore, considering strategic steps, such as securing a consistent feedstock supply, handling grade fluctuations, and optimizing transportation expenses and emissions, can facilitate the efficient expansion of biofuels and set refiner performance apart."

As an example, the report cites the joint venture between Marathon Petroleum Corp. (Findlay, Ohio; www.marathonpetroleum.com) and ADM (Chicago, Ill.; www.adm.com) for establishing a specialized soybean-processing facility to generate refined vegetable-oil feedstock for renewable-diesel production. The facility (Green Bison Soy Processing), opened in late 2023 in North Dakota.

For its part, Chevron is also developing capacity for producing renewable diesel and SAF using the hydrotreated esters and fatty acids (HEFA) route. The company is putting a lot of effort into developing new catalysts to improve the HEFA process and increase its efficiency, Chevron's Jablonski says. "We are also repurposing existing equipment for making renewable fuels, while also preserving the swing-back capability to go back to making conventional fuels, if customer demand warrants it," he says.

Simultaneously, Chevron is also working to develop feedstocks for renewable fuels that lower carbon intensity and help improve scalability, Jablonski notes, in addition to studying how to obtain fuels from new oil-yielding crops, lignocellulosic biomass and algae. "We're trying to align that work with catalyst and process development, so the activities complement each other," he says.

In one example, Jablonski points to a 2023 project on low-carbon-intensity gasoline, in which Chevron partnered with automaker Toyota to make gasoline that Chevron says is comparable to battery-powered cars on a lifecycle basis, with respect to carbon intensity. Chevron's renewable gasoline blend, made from both biomass and conventional components, contains more than half renewable materials, the company says, claiming it can reduce lifecycle CO_2 emissions by more than 40% compared to traditional gasoline. Last year, the drop-in fuel replacement was used in a demonstration project involving three Toyota vehicles driving from Mississippi to Texas (Figure 3).

In other recent renewable-fuel developments, the Italian energy company Eni SpA (Rome; www.eni.com) in January 2024 confirmed that it will

FIGURE 3. Last year, a demonstration project involving Chevron and Toyota used a blend of renewable and conventional gasoline to power a roadtrip across southern U.S. states

move ahead with plans to convert its facility in Livorno into a biorefinery. And in April of this year, Phillips 66 (Houston, Texas; www.phillips66.com) announced progress in converting its San Francisco refinery into the Rodeo Renewable Energy Complex. The facility now processes only renewable feedstocks, producing approximately 30,000 bbl/d of renewable diesel. Repsol S.A. (Madrid, Spain; www.repsol.com) announced in April the start of large-scale production of renewable fuels at its industrial complex in Cartagena (Spain).

Turning to SAF, TotalEnergies SE (Paris; www.totalenergies.com) and China Petroleum and Chemical Corp. (Sinopec; Beijing; www.sinopec.com) signed a preliminary agreement in March 2024 to jointly develop a SAF production unit at a Sinopec refinery in China. The planned unit will have the capacity to produce 230,000 tons of SAF per year, and will process local waste cooking oils and animal fats.

Decisions and digitalization

For refinery leaders, the pace of change for decision making has accelerated greatly in the last decade and the evolution of technology has also accelerated. "The frequency and pace at which you have to make decisions is much faster now than at any time in the past," Chevron's Jablonski says, "so we need to accelerate decision-making, but we also need to maintain flexibility to be able to meet long-term investment challenges and maintain viability in the long term."

Making investment decisions that strike a balance between maintaining the current security of supply and operation with flexibility for the energy transition is among the top three current refinery challenges, agrees Shell C&T.

To address the challenges, an area of focus has been digitalization tools, such as artificial intelligence/machine learning (AI/ML) and digital twins. Jablonski says, "We've seen great potential for AI/ML for predictive maintenance to improve operational availability and streamline turnarounds," and AI has also been great for materials development R&D for catalysis, he adds. The company has also seen value from developing a digital twin program, Jablonski notes.

Shell C&T says digitalization (of unit monitoring, for example) has led to better and faster access and exchange of data. "We can make data-based decisions and recommendations for optimization much faster and effectively. This improved data exchange has enabled a faster feedback loop for improving catalyst developments and predictive modeling," the company says.

Further, Shell C&T says "[AI] and improved computing analytics have improved our ability to monitor, model and develop new technologies for refining. We employ machine learning techniques to accelerate our catalyst development and targeting. We also use advanced computational modeling to better understand the interaction of catalyst active sites with reactant molecules."

Jade Rodysill, the global and Americas chemicals and advanced materials industry leader at EY (New York, NY; www.ey.com), says $1 billion had been invested in AI technologies by the chemicals industry as of 2022, but by 2032, the total will exceed $17 billion, with at least $1.5 billion aimed specifically at generative AI technology.

"There are a lot of good use cases for AI … but a concern is data — there are plenty of data, but it needs to be contextualized and trusted to be useful in AI applications," Rodysill says.

Wood Mackenzie's Lin says "Digital tools are still in their infancy in manufacturing, with many companies working to identify where they can add value. For now, much of the focus has been on reliability, and leveraging technology to better schedule predictive maintenance to avoid downtime."

And on the process side, "the integration of economic modeling with process-control schemes has been an ongoing journey, as refiners move from base layer to advanced process control," Lin explains. "The next step as part of a digital journey is to incorporate larger-scale economic models with unit operations, enabling control schemes that span multiple process units and employ more sophisticated economic optimizers," he says.

Rodysill says AI can already be effective in demand planning and optimizing plant yields more holistically than what was possible in the past. Also, AI has the ability to eliminate human bias in forecasting, he adds.

Chevron's Jablonski cites the example of real-time optimization (RTO). "In the past, RTO has been done with a systematic, phased plan with steps, but today, we can do it more holistically across the full value chain and more continuously also, from feedstock selection, to process, to the response to pricing and demand changes in the markets."

The attention on digitalization tools is also prompting the industry to develop employees with the necessary skill set for taking advantage of these technologies. For example, Chevron has been developing digital skills in their engineer cohort through a Digital Scholars Program. To achieve the necessary combination of digital skills, including knowledge of data science, with a basis of domain knowledge in refining and processing, the company has been sending Chevron engineers to get master's degrees in data science from top universities. "It's a significant commitment, but it's worth it," Jablonski says. ■

Scott Jenkins

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Editor's note: For additional information, including more on catalysts and refinery operations, see the online version of this article at www.chemengonline.com.

Industrial Robots Forge Ahead

Performance improvements in robotics technologies for manufacturing and energy operations are leading to greater productivity, cost savings and safety improvements

In the chemical process industries (CPI), mobile robots, often in conjunction with artificial intelligence (AI) and machine learning (ML), are currently being deployed for a handful of tasks — usually those that present safety risk to workers, or that are overly expensive for plant personnel to undertake. The most common task that may come to mind is the simple movement of inventory, such as chemical tanks, between locations, but robotic devices are also becoming increasingly involved in tasks like equipment inspections and waste cleanup. This article looks at some of the advancements in robotics technologies that are being applied in CPI facilities.

Versatility and adaptability

"Robots can perform operator rounds with many human-like capabilities, such as hearing, seeing, smelling and feeling. Robots do this by taking photos or videos, recording sound and vibration signatures and detecting hot and cold spots via thermal-imaging cameras," states Sandra Fabiano, the robotics engineering manager of Yokogawa Corp.

FIGURE 1. Robotic arms can prove very helpful in manufacturing applications that require precision and repeatability, as in the manufacture of batteries and fuel cells

of America (Sugar Land, Tex.; www.yokogawa.com/us).

Yokogawa recognized that there is no one perfect mobile robot for these tasks — those in the market offer similar solutions, but all possess different capabilities and environmental limits. With all this in mind, Yokogawa identified the need for a fleet-management platform that can handle any mobile robot and be integrated into other plant automation systems. "Since user requirements vary widely, the only way to meet all the needs is to offer robots from different vendors. For instance, we may use one type of robot for indoor settings where stair traversal is necessary, and another in hazardous areas, which require explosion-proof equipment," says Fabiano.

In March, Yokogawa launched its Oprex Robot Management Core software application, which integrates the management of several types of robots to perform inspection tasks. Fabiano added, "The platform provides a common user interface, data storage for all vendor-robot data, and the ability to use in-house or third-party AI services to integrate with industrial automation systems." Currently, the robots that are supported include Boston Dynamics' Spot and Mitsubishi Heavy Industries' EX ROVR.

Robots also add another layer of convenience to help alleviate certain workforce concerns — namely, the "great crew change," where companies expect to lose over half of their workers to retirement in the coming years. "Robots use artificial intelligence to meet customer requirements, such as distinguishing between safe and hazardous conditions and detecting anomalies to bring a process back within specification. The accuracy of AI and consistency of the data capture by robots are essential to providing effective knowledge for operational efficiency and production quality," says Penny Chen, Yokogawa's senior principal technology strategist.

FIGURE 2. Robotic inspection and surveillance can help protect water infrastructure against deterioration and water losses

Yokogawa has worked on several proof-of-concepts using mobile robots. Last year, the company announced a project to deploy quadruped robots to perform plant inspections and maintenance at Cosmo Oil Co.'s Yokkaichi petroleum refinery in Japan.

Precision and repeatability

Industrial robots provide many advantages in manufacturing environments that require extreme precision, hygiene and repeatability, such as in the production of membrane electrode assemblies (MEAs) for fuel cells. Stäubli International AG (Pfäffikon, Switzerland; www.staubli.com) has provided robots for what is said to be the world's first fully automated production line for fuel cells, operated by Palcan Group in Cixi, China. MEAs present special challenges in mass production, since they are fabricated by stacking hundreds of very thin layers of expensive and fragile

INDUSTRIAL ROBOTICS 101

Current applications

Material handling. Robots are used to transport raw materials, finished products and hazardous substances within plants. This minimizes human exposure to dangerous chemicals and reduces the potential for accidents during material transfer.

Mixing and sampling. Robotic systems can handle the mixing of chemicals with high precision, consistency and repeatability. They can also perform automated sampling and testing to ensure product quality and process optimization.

Packaging and palletizing. End-of-line robotics can package chemical products and palletize them for shipment. Automation in this area can significantly increase throughput and reduce labor costs.

Inspection and quality control. Robots equipped with advanced vision systems can inspect containers, labels and seals for defects. This helps maintain high quality standards and compliance with industry regulations.

Assembly of components. In the production of chemical sensors, pumps or other devices, robots can assemble small and intricate components with high precision and speed.

Cleaning and maintenance. Robots can be used to clean reactors, tanks and other equipment in a chemical plant. Automated cleaning systems can work in environments that are unsafe for human workers due to toxic substances or extreme conditions.

Hazardous environment operations. Robots can operate in extreme conditions, such as high-temperature areas, or in environments with a risk of explosion or contamination, reducing the need for human exposure.

Laboratory automation. In research and quality-control laboratories, robots can conduct automated chemical analyses, handle reagents and prepare samples, leading to faster development cycles and consistent testing.

Process control. Robotic interfaces with advanced control systems can manage and monitor chemical processes, adjusting parameters in real time for optimal reactions and energy consumption.

Emergency response. Specialized robots can be used for emergency situations, such as chemical spills, fires or leaks. They can assess the scene, collect data and even perform cleanup or containment tasks.

Potential benefits

Enhanced safety. Robots can operate in hazardous environments where there may be exposure to toxic chemicals, extreme temperatures or high pressure, leading to fewer accidents and injuries.

Increased efficiency. Robotics can perform tasks at a higher speed and with greater precision than human workers. This can lead to increased productivity and throughput, helping companies to meet high demand and tight deadlines.

Consistent quality. Robots can maintain a high level of consistency in their work, which is particularly important in the CPI, where precise measurements and mixing are critical. Automation helps to ensure consistent product quality, batch after batch.

Reduced downtime. Robots can operate around the clock without the need for regular breaks, reducing downtime and increasing overall production time.

Cost savings. Although the initial investment in robotics can be significant, over time, robotic systems can reduce labor costs and increase production efficiency, resulting in cost savings for the company.

Improved data collection. Modern robotics systems are often equipped with sensors and can be integrated with data-analytics tools to provide valuable data on process efficiency, machine performance and product quality. Such data can be used to further optimize processes and predict maintenance needs.

Environmental considerations. Automation can help achieve more precise control over processes, such as mixing and chemical reactions, leading to reduced waste and emissions. This is not only beneficial for the environment but can also be cost-effective.

Scalability. Robotic systems can be scaled up or down to meet changing production needs without the same constraints faced by a human workforce.

Versatility. Advanced robots can be reprogrammed and fitted with different tools to perform a variety of tasks, making them adaptable to changing production needs or to the development of new products.

Innovation. Robotic technologies often drive innovation by enabling new processes and techniques that can lead to the development of new products and services within the chemical and energy sectors.

The next generation

Advanced AI and ML integration. Robots equipped with AI algorithms can improve their performance over time through ML techniques. This will allow robots to adapt to new tasks more quickly, perform complex decision-making and improve their efficiency and autonomy.

Enhanced sensory capabilities. The development of more sophisticated sensors will enable robots to have a better understanding of their environment. This will enhance their ability to perform tasks that require delicate handling, precise measurements and quality-control inspections.

Collaborative robots (cobots). Cobots are designed to work alongside human workers safely, and are becoming increasingly responsive and adaptable. They can take on repetitive or hazardous tasks, freeing up human workers for more complex problem-solving activities.

Increased mobility. With the development of more advanced mobile robots and drones, robots will become more capable of performing a wider range of tasks in various environments, including hard-to-reach areas in manufacturing plants or remote energy facilities.

Energy-specific robotics. Robotics designed for inspection and repair of energy infrastructure, such as pipelines, offshore platforms and wind turbines, will advance to tackle the unique challenges presented by these environments, including underwater and aerial navigation.

Internet of things (IoT) integration. Robots will be more interconnected with a wider array of devices and systems, allowing for better data collection, real-time monitoring and predictive maintenance. This will improve overall operational efficiency and reduce downtime.

Additive manufacturing robots. With the advancement of 3D printing, robots will increasingly be used in additive manufacturing processes to produce complex components on-demand, which can revolutionize inventory management and supply chains.

Smart material handling. In the energy sector, smart robotic systems will be employed for handling hazardous materials, reducing the risk of contamination and exposure.

Nano-robotics. Although still largely in the research phase, nano-robots could radically transform the manufacturing and energy sectors by enabling new processes at the molecular and atomic scale, such as targeted drug delivery or ultra-precision manufacturing.

"Green" robotics. With the growing focus on sustainability, there is an increasing demand for robots that can assist in the creation and maintenance of sustainable energy systems, such as solar-panel installation, cleaning and recycling operations. ❑

Content contributed by Sebastien Schmitt, Robotics Director, North America, Stäubli

materials, but robots have helped to streamline the process. Robotic arms (Figure 1) not only position coated carbon sheets to begin the stacking process, but also handle films that must be soaked in a strong acidic solution, which would pose hazards to workers. Stäubli's robots not only can handle the extremely acidic environment, but also high humidity, without any corrosion.

The company has also supplied robots for the manufacturing of lithium-ion batteries, pharmaceuticals and many other products. "Emerging applications and performance improvements in robotics technology will enhance the capabilities of robots

in manufacturing and energy operations, leading to greater productivity, cost savings and safety improvements in industry. As technology continues to evolve, businesses in the chemicals and energy sectors will likely find new and innovative uses for robotic systems," says Sebastien Schmitt, robotics director for North America at Stäubli. Such advancements on the horizon include integration with more advanced AI and ML algorithms, enhanced sensory capabilities to give robots a better understanding of their environment and increased mobility to perform a wider range of tasks in hard-to-reach areas. For more on robotics from Stäubli's Schmitt, see the box on p. 18.

As in manufacturing applications, the water-processing sector involves critical infrastructure for society, as well as hazards and confined spaces that present safety risks for workers. Fluid Analytics Ltd. (Santa Clara, Calif.; www.fluidanalytics.ai) has designed several AI and robotic technologies targeted at the water-processing sector, including AI-based pipeline-inspection software and a robotics and IoT platform for surveillance of wastewater-processing infrastructure (Figure 2). "The water sector relies heavily on tanks and pipelines for the transport of liquids across several processes and requires this infrastructure to perform as designed to prevent catastrophic failures. Fluid Analytics' robots are commonly deployed for pipeline infrastructure inspections where there is a risk of human exposure to toxic chemicals," says Asim Bhalerao, CEO of Fluid Analytics. Using robotics to automate such routine monitoring and surveillance of pipelines carrying wastewater and chemical effluents is very advantageous for worker safety, since the concentrations of toxic chemicals and dangerous biological microbes are often high. By proactively mapping out pipe networks, detecting signs of deterioration or leaks, water loss is significantly reduced, as are risks for environmental damage.

"Through its repeatable and precise monitoring capabilities, Fluid Analytics' platform has helped to reduce the discharge of over 200 million gal/d of toxic fluids into urban waterways," says Bhalerao. Notably, Fluid Analytics' monitoring platform helped to detect the presence of the Omicron variant of the SARS-CoV-2 virus in India's wastewater, days before the first reported clinical case.

Remotely control water cleanup

At the 2024 AIChE Spring Meeting (March 24–29; New Orleans, La.; www.aiche.org), Cyril Castello, commercial director for IADYS (Roquefort-la-Bédoule, France; www.iadys.com) presented a unique robotic device that has already found use in several large chemical-manufacturing complexes. The Jellyfishbot (Figure 3) is a small robotic device designed for monitoring and cleaning bodies of water. Jellyfishbot devices have been deployed globally at industrial sites to clean up plastics and oil spills in water bodies adjacent to production plants. Industrial users include Dow Chemical, LyondellBasell, ExxonMobil, Veolia, TotalEnergies, Toyota and many more. According to Castello, for cleanup of plastics, the robot can be outfitted with a specialized net for collecting microplastics

FIGURE 3. These remotely controlled robotic devices are designed for cleaning debris and pollution from water surfaces

in water. Besides their cleaning capabilities, Jellyfishbot robots also can be equipped with water-quality sensors to measure temperature, salinity, turbidity and cyanobacteria and phytoplankton concentrations.

At Dow's manufacturing site in Freeport, Tex., Jellyfishbots have been deployed to clean debris, such as plastic pellets or overgrown algae, out of stormwater conveyance systems, meaning that humans no longer need to access these areas during extreme heat or potential flood situations. The autonomous nature and onboard sensors of the robots allow them to navigate their environment seamlessly, minimizing collision with walls or other obstacles. The robots can communicate via wireless, Bluetooth or 5G connectivity, so remote control is possible in any plant area as needed. The next step for Dow will be to install a floating docking station — which IADYS is commercially launching this year — so that the robot can automatically dock itself when charging is required. "With the docking station, which will recharge the robot, allow it to offload the net and will clean the robot, we're definitely taking things to the next level. We are also thinking about a supervision platform to enable the use of a fleet of robots (several dozen) without any manual intervention," says Castello.

FIGURE 4. Robots can quickly deploy containment booms for faster remediation of oil spills

Besides Dow, IADYS is partnering with several other plants in the U.S. Gulf Coast region that are part of the Operation Clean Sweep (OCS) program aimed at reducing plastic pollution in water.

The newest generation of IADYS robot is the Mobile Oil Skimmer (MOS), which equips a Jellyfishbot with a storage platform and skimmer. Said to be the first mobile oil-cleanup device, the MOS can collect oil from the surface of water and store it in an onboard 120-L tank. According to the company, the MOS can achieve a fast skimming rate of 3.5 L/min, which is essential for containing oil spills and minimizing environmental damage. Also helpful is the robots' ability to rapidly deploy the containment booms used for spill response (Figure 4).

Advances in teleoperation

The second Advanced Industrial Robotic Applications (AIRA) Challenge (www.aira-challenge.com) will take place at the Achema World Forum and Tradeshow (June 10–14; Frankfurt am Main, Germany; www.achema.de). The AIRA Challenge will bring together some of most advanced mobile robots in the world with the goal of developing new robotics technologies that can execute tasks remotely in chemical processing plants. At the previous AIRA Challenge, held at Achema in 2022, the goal was to provide proof-of-concepts for fully autonomous mobile robots (Figure 5). However, for the 2024 challenge, the focus is moving beyond full automation to a more dynamic and communicative model for robots. "Making robots fully autonomous takes enormous effort to program everything, so we wanted to expand the business case for autonomous robots. Now, we're not just looking for an autonomous robot, but one that can communicate its needs to operators," explains Carl-Helmut Coulon, head of future manufacturing concepts at Invite GmbH (Leverkusen Germany; www.invite-research.com), the organizer of the AIRA Challenge.

Giving robots the ability to "call for help" when an unknown situation is encountered helps to lower the programming barrier for automaticity, says Coulon. "You can program

FIGURE 5. The AIRA Challenge has helped to push the boundaries of automation in mobile robots

in the easiest 80% of the solution, and then any situation that the robot cannot handle by itself can be communicated to and dealt with by the operator," he explains. While it may seem like reducing the amount of automation in a robot might decrease its complexity and capabilities, there are many benefits to the teleoperation approach that AIRA is looking for. "We want to upgrade the robots to enable remote control of the robot from a distance with no line of sight, and also add virtual reality to navigate. This gives the robot flexibility to open and close doors, dispose of waste, inspect closed cabinets and take material samples," says Coulon.

He believes that the flexibility enabled by teleoperation will increase the business use cases for mobile robots in chemical plants and warehouses and encourage their adoption in industry. In theory, operators could take control of a robot at a plant thousands of kilometers away to respond to an alarm or evaluate the severity of a situation and decide whether or not in-person intervention is required.

"We see teleoperation as an extension of classical autonomous mobile operations. At the challenge, we expect to see mobile robotics capabilities that have never been seen before," adds Coulon. The 2024 AIRA Challenge finalists, listed below, were selected by a judging group consisting of experts from BASF, Bayer, Wacker and Boehringer Ingelheim.

- EngRoTec Group (Hünfeld, Germany; www.engrotec.de)
- ETH Zurich's Robotic Systems Lab (Switzerland; rsl.ethz.ch)
- Forschungzentrum für Informatik (Karlsruhe, Germany; www.fzi.de)
- Reply Roboverse (Munich; www.reply.com/roboverse-reply)
- Team TruPhysics/United Robotics Group (Stuttgart, Germany; www.truphysics.com) ■

Mary Page Bailey

Representing Particle Size and Geometry

Department Editor: Scott Jenkins

Particle size and shape, as well as particle size distribution (PSD) are key determinants of bulk solids behavior [*1–4*]. A particle can be defined as a single unit of material having discrete physical boundaries that define its size. Particle science is typically limited to particulate systems within a size range from 10^{-3} to 10^{4} µm.

The measurement and selection of appropriate average particle size is a difficult task because of inherent particle characteristics. Particle shapes are often irregular, so describing a particle's size is not straightforward. This one-page reference provides information on methods for describing and measuring particle size.

Particle geometry effects

The bulk behavior of particulate material is greatly dependent on its geometric properties at those scales. In industrial processes, particle size and shape affect phenomena such as the following [*2*]:

- Catalyst-material reactivity
- Bioactivity and dissolution of pharmaceutical agents
- Setting time of cement
- Agglomeration
- Sedimentation rate
- Flow through porous media
- Flowability of powder
- Packing density of materials
- Permeability of packed beds
- Rate of settling by particles in a fluid
- Gas-solid separation efficiency in a cyclone

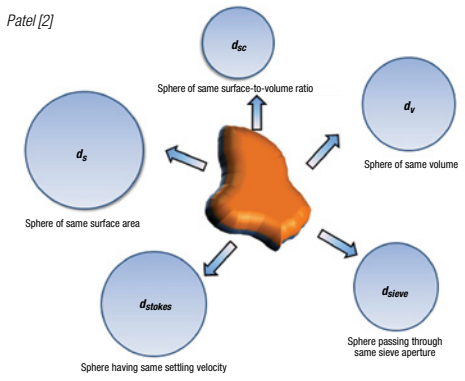

FIGURE 1. With the equivalent spherical diameter approach, particle sizes are represented by an equivalent sphere with the same controlling characteristics (volume, surface area, others) as the particle

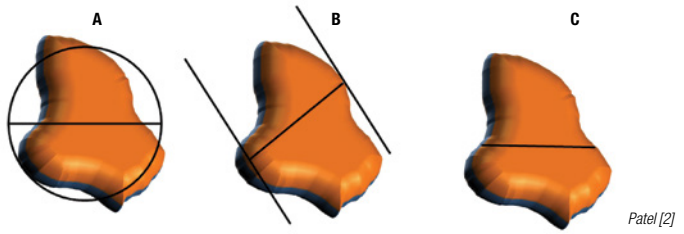

FIGURE 2. Statistical diameters of a particle can be defined in different ways. Commonly used ones are Feret's (B) and Martin's (C)

TABLE 1. PARTICLE-SIZE-MEASURING TECHNIQUES AND SIZE RANGES

Instrument Techniques	Size range, µm
Mechanical sieving (dry)	38 to 100,000
Mechanical sieving (wet)	20 to 3,000
Air jet sieving	20 to 200
Ultrasonic sieving	5 to 100
Gravimetric sedimentation	1 to 3,000
Coulter counter	0.5 to 300
Laser-light diffraction	0.02 to 1,000
Centrifugal sedimentation	0.01 to 10
Microscopic image analysis	0.01 to 1

- Solids mixing and segregation of solid ingredients
- Handling of solids-containing fluids

Describing particle size

Specifying the sizes of irregularly shaped particles is commonly conceived by representing the size using a simple linear dimensional descriptor, such as diameter. However, because solid partricles are irregular and non-uniform, determing the diameter of a non-spherical particle depends on how it is measured. There are several approaches available to representing the size of a particle, categorized into three areas described below.

Equivalent spherical diameter. Equivalent-spherical-diameter methods determine diameters by measuring a size-dependent property of the particle and relating it to a single linear dimension [*2*]. The equivalent sphere diameter takes advantage of the ideal shape of a sphere represented by the single dimension. The equivalent spherical diameter is the diameter of a sphere that shows the same controlling characteristics as the particle under investigation. The controlling characteristics could be volume, surface area, surface-area-to-volume ratio, settling velocity or other characteristics. Several commonly used equivalent-sphere diameters are shown in Figure 1.

Stoke's diameter is the diameter of a sphere (d_{st}) having the same density and settling velocity as the particle under investigation in laminar flow conditions.

Statistical diameter. The commonly used statistical diameters are Feret's diameter and Martin's diameter. Feret's diameter is defined as the distance between two parallel tangents, while Martin's diameter is defined as a length of the chord that bisects the particle outline (Figure 2).

Equivalent circle diameter. Equivalent circle diameters, such as the projected area diameter (area of circle with the same area as the projected area of the particle under investigation), can also be used (Figure 2A). These measures are outdated due to their statistical nature and poor reproducibility because there are many possibilities to estimate distance between tangents and bisector.

Measuring particle size

There is no single standard method to measure particle size. Each method has pros and cons. Some of the standard methods that are used to measure particle size and size ranges are shown in Table 1 [*3*]. ■

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Ion-Exchange Resins: Solutions for a Wide Range of Challenges

A large selection of ion-exchange resins is available today for a constantly growing variety of applications. In order to choose the appropriate resin for a specific application, it is important to carefully evaluate the range of resin and process properties and parameters

Stefan Hilger
Lanxess Deutschland GmbH

IN BRIEF

Various inorganic and organic materials of both natural and synthetic origin, among them clays, peat, zeolites or metal silicates, are prone to exchange bound ions with other ions from a surrounding liquid phase.

This article focuses on ion-exchange (IEX) resins [*1*] — that is, functionalized organic polymers. In the early days, these were mainly phenol-formaldehyde polymers, but today, IEX resins are most importantly derived from vinylbenzenes or acrylates. Besides ion exchange, some of these materials are also able to function as an absorber for uncharged, polar and even nonpolar molecules, which further widens the application opportunities.

Four main types of IEX resins have been developed over time. They are categorized [*2*] as strong and weak acid cation-exchange resins (SAC/WAC) on one hand and strong and weak basic anion-exchange resins (SBA/WBA) on the other hand.

Since they were first produced back in the late 1930s in Wolfen, Saxony-Anhalt, Germany [*3*], polystyrene-based IEX resins have been employed in a variety of applications. Softening and demineralization of water have been of focal importance for decades and still play a major role, not only for industrial applications — for example, in power-plant cooling circuits [*4*], for the preparation of ultrapure water for use in medical applications and in the food, beverage and semiconductor industries — but also for municipal water treatment and household use.

IEX resins based on polystyrene and polyacrylates account for the great majority of products in today's global markets. For industrial applications, polystyrene-based resins are often favored due to their better stability, leading to longer service life. These resins can handle high and also variable flowrates, as well as acids and bases in fairly high concentrations.

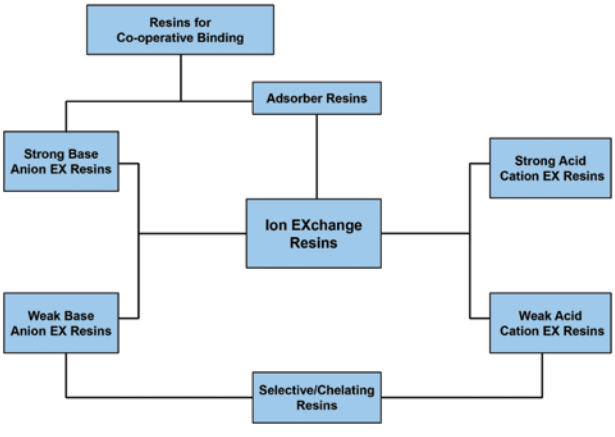

FIGURE 1. Ion-exchange (IEX) resins can be classified into various classes and subclasses

Competing technologies

Even for demineralization, quite a few technologies are available today besides ion exchange. Reverse osmosis (RO), for example, can also remove dissolved ionic substances quite efficiently [*5*]. The membranes employed, however, are frequently susceptible to fouling and can have difficulties when dealing with variable flowrates. Very low ion concentrations in permeates can only be achieved with difficulties at the price of repeated, energy-consuming treatment.

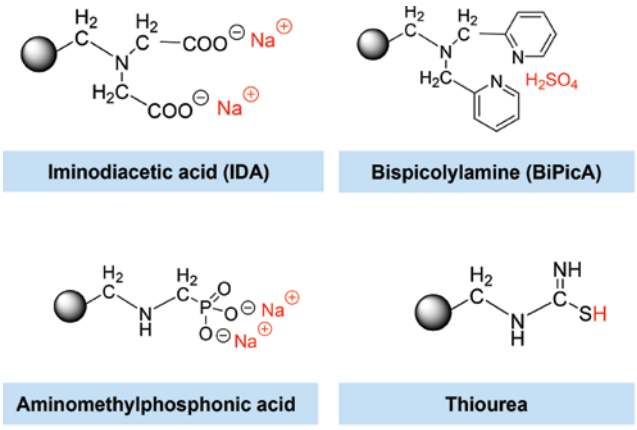

FIGURE 2. Here is an overview of specialized IEX resins by functional group

Electrodeionization (EDI) [*6*], as another example, requires a relatively high-energy input and also has difficulties in obtaining water resistivity above 16 MΩ, as is required for ultra-pure water. Silica is especially difficult to remove in one single step. EDI systems generally have a very low tolerance for hardness ions and organic matter due to blocking of the membranes. Furthermore, maintenance and replacement cannot easily be split into a device and an active component as is possible with an IEX system.

In contrast to IEX with resins that can be tailored to be highly selective (see below), both RO and EDI exhibit only very limited ion selectivity, if any. Therefore, both the latter methods can only remove the dissolved ion contents as a whole. In all these respects, an IEX resin system exhibits superior properties that make it favorable whenever one or more of the requirements mentioned above are crucial.

However, IEX resins also have limitations. Although the stability against oxidative stress is significantly better with IEX compared to RO and EDI, oxidizing agents may markedly limit the service life especially of anion exchange resins. Due to their polymeric backbone, operating temperatures for most types of polystyrene-based resins are limited to approximately 140°C (SAC/WAC) and 70°C (SBA/WBA, chloride form) or 40–45°C (SBA/WBA, OH form). SBA and WBA resins on acrylate basis are more sensitive to elevated temperatures. Even in chloride form they should not be employed at temperatures above 40°C.

Capabilities of IEX resins

Besides the four functionalization classes of IEX resins mentioned above, additional subclasses can be identified that contain special functional groups, such as bi- or polydentate groups, which are capable of forming chelating complexes with enhanced selectivity. Additionally, certain resins may also allow for non-ionic interactions with substrates, thus establishing co-operative binding modes (Figure 1).

Selectivity

Di- versus monovalent ions. A key property of modern IEX resins is their selectivity, which goes far beyond

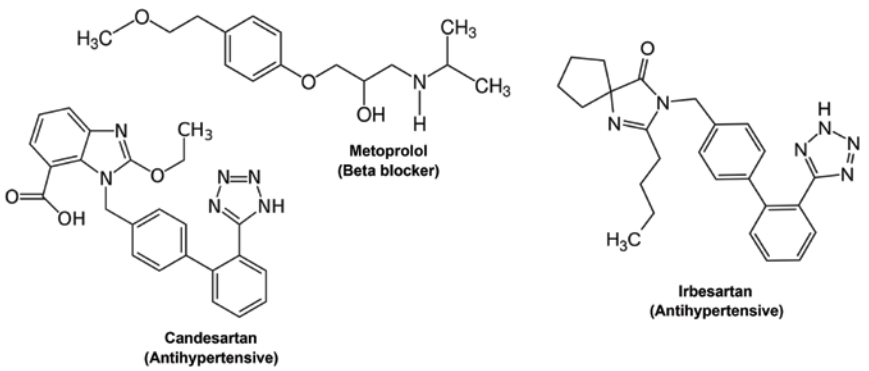

FIGURE 3. These three structures are typical micropollutants that can be removed by interaction with IEX resins

that simply for anions or cations in general. Resins can easily discriminate between monovalent and divalent ions, for example, due to a markedly different binding strength. These differences in selectivity usually increase with a higher degree of cross-linking, that is, a higher share of divinylbenzene added as cross-linking agent during polymerization, as shown in Table 1 [*7*].

For trivalent ions, selectivity differences may be even more pronounced. Special IEX resins exhibit small bead size and very fast kinetics. Therefore, even a partial separation of rare-earth ions, namely of lanthanum, cerium, praseodymium and neodymium, from other rare earth, earth alkali and aluminum ions is possible [*8*]. Separations of this kind are considered to be the most difficult of all.

Specific ions. Appropriately functionalized resins can even be tailored to preferentially bind a specific ion, allowing for a partial or even almost complete separation of mixtures [*9*]. Most often, this selectivity is due to chelating functional groups, that is, ionic or polar groups that can establish more than one (ionic) contact to the substrate ion in the course of complexation (Figure 2).

As an example, the removal of calcium and magnesium ions is possible even from concentrated brine using a special SAC resin with small beads [*10*]. The absence of earth alkali cations is a crucial requirement in chlor-alkali electrolysis in order to prevent blocking of the cell membranes and enhance the efficiency of the electrolysis. The concentration of these divalent ions needs to be reduced down to the single-digit parts-per-billion (ppb) range for this purpose. In a similar process, calcium in a wide concentration range can also be separated from lithium brine by ion exchange during the production of battery-grade lithium salts. Even lithium itself can be recovered in the form of lithium aluminates from brine with special resins that have been modified with aluminum salts [*11*].

Selective binding of ions can also be a solution for medical treatment, as exemplified by IEX resins that — after oral administration — selectively bind potassium ions and can thus be use to treat hyperkalemia [12, *13*]. The resin binds potassium in the digestive tract and is then excreted in a loaded form. Further medical applications include the controlled release of active pharmaceutical ingredients over an extended period of time. IEX resins can also be employed as excipients in medical formulations [*14*], for example, as a taste masking agent in orally administered drugs [*15*] containing, for instance, antibiotics with a bitter taste or nicotine for smoking cessation. The mechanism involves the drug being initially bound to the resin. The complexation retains structural integrity in the neutral oral environment. Under the acidic environment in the stomach, the medicine is then released from the resin after being replaced by protons [*16*].

An application that has gained substantial interest recently in the course of the fight against climate change is direct air capture (DAC) of carbon dioxide facilitated by SBA or WBA resins [*17, 18*]. This is one of several carbon capture and storage (CCS) technologies that have

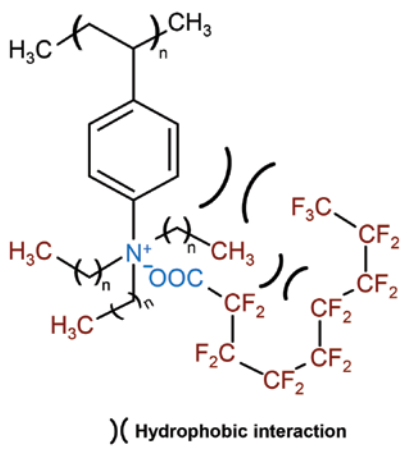

FIGURE 4. Shown here is the cooperative binding of a long-chain PFAS molecule (perfluorononanoic acid; PFNA) to a polystyrene-based SBA (strongly basic anion)

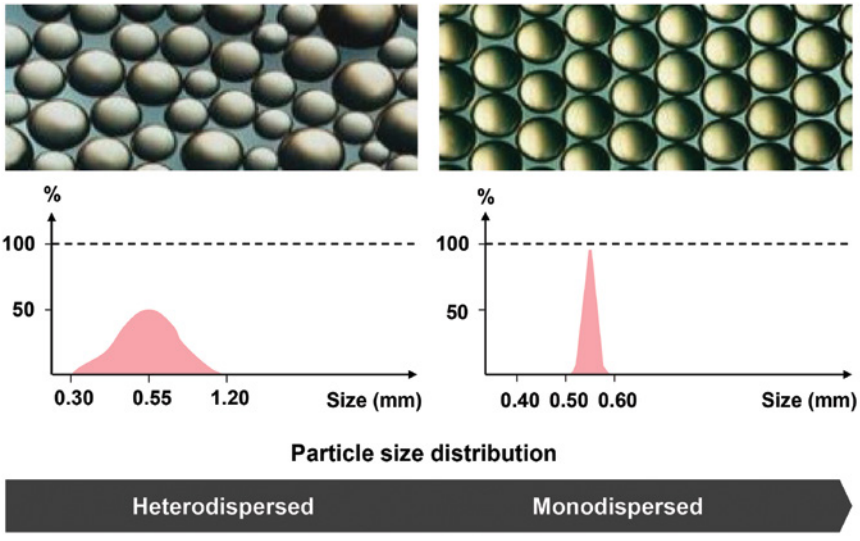

FIGURE 5. The particle-size distribution is much narrower for monodispersed resins compared to heterodispersed resins

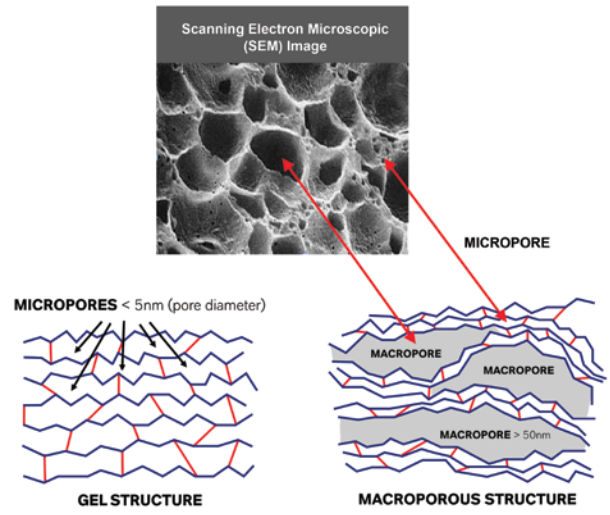

FIGURE 6. This diagram compares the structures of gel-type and macroporous IEX resins, as observed by SEM imaging

been proposed and implemented to reduce CO_2 emissions from point sources.

Hydrophobic interactions

Additionally, IEX resins can even bind uncharged molecules by adsorption. This is due to weak polar interactions and can, for example, be employed to separate micro-pollutants containing aromatic rings, such as active pharmaceutical ingredients, pesticides or non-ionic detergents (Figure 3) during municipal wastewater treatment [*19–21*]. The IEX resin is more efficient than activated carbon with high loading capacity, high mechanical stability and exhibits fast exchange kinetics, which allows the use of small, compact filters instead of large columns.

Cooperative binding situations can also occur. In such cases, a substrate molecule is simultaneously bound to the IEX resin by means of ionic and hydrophobic interactions (Figure 4). Such a behavior is observed during removal of long-chain PFAS (per- and polyfluoroalkyl substances), for example, perfluorononanoic acid (PFNA) from wastewater. PFAS molecules usually consist of a polar "head" (carboxylic acid) and a nonpolar "tail" (per- or polyfluorinated carbon chain). While the former is bound to the IEX resin via Coulombic attraction, the latter establishes weak interactions with aromatic π-electron systems of the polystyrene backbone of the resin.

Selection parameters for resins

Even if there are many characteristics that determine which resin is best suited for a particular application, some basic parameters will be discussed here due to their general importance, namely uniformity, morphology, bead size and the life-cycle sequence.

Uniformity. For more than four decades now, specialized polymerization processes are available for the production of resins of uniform particle size (monodispersed resins) [*22*]. These resins offer significant advantages over heterodispersed products, including the following:

TABLE 1. RELATIVE SELECTIVITY COEFFICIENTS (H^+ = 1) OF SAC RESINS AS A FUNCTION OF THE DEGREE OF CROSSLINKING*

DVB	4%	8%	12%	16%
H^+	1	1	1	1
Na^+	1.3	1.5	1.7	1.9
NH_4^+	1.6	1.95	2.3	2.5
Mg^{2+}	2.4	2.5	2.6	2.8
Ca^{2+}	3.4	3.9	4.6	5.8
Sr^{2+}	3.85	4.95	6.25	8.1
Ba^{2+}	6.15	8.7	11.6	16.5

Note: DVB = divinylbenzene; SAC = strong acid cation exchange

- Fewer fine and fewer coarse beads leading to less ion leakage and better regeneration performance
- Higher operating capacity due to more uniform flow over the surface and less tendency for channel formation
- Lower pressure drop due to the existence of evenly wide, unblocked channels between the beads to enable high flowrates
- Higher mechanical stability due to homogeneous, optimized functionalization — longer service life, less generation of fines, which would increase the pressure drop
- Higher osmotic shock stability — especially important for macroporous chelating resins, for example when a chelating resin loaded with calcium as obtained from brine polishing for chlor-alkali electrolysis (see above) is regenerated with hydrochloric acid and afterwards conditioned with caustic soda solution. The latter causes osmotic stress resulting from a 60% increase in volume.

Today, most of the monodispersed resins are based on polystyrene as polymeric backbone. Polyacrylate resins are mostly heterodispersed due to the lack of an economically feasible production process. However, membrane emulsification processes were developed in recent years for this purpose [*23*]. Currently, most acrylate resins belong to the WAC class of resins, where this is not of crucial importance.

Morphology. Basically, two types of resin can be distinguished in terms of morphology (Figure 6). In gel-type or microporous resins, on one hand, the bead surface is covered by a gel layer containing the functional groups that are easily available for ion exchange. The micropores are usually less than 2 nm in diameter. Gel-type resins exhibit high operative capacities. Typical applications include acid-catalyzed reactions with gel-type SAC resins such as dehydrations, (co-)condensations, esterifications and Friedel-Crafts-type alkylations [*24*]. However, their surface is sensitive to fouling, induced, for example, by natural organic matter (NOM), which makes access to the functional groups more difficult.

In macroporous resins, on the other hand, not only the bead surface, but also wide channels of more than 50 nm in diameter within the bead are equipped with functional groups. This leads to a markedly increased active surface and enhanced mechanical stability of the beads. Because of their high mechanical and osmotic stability, they are employed in a variety of processes, including those in non-aqueous solvents, such as for binding heavy metal ions. Whenever a high total capacity and therefore a high degree of cross-linking is required and at the same time stable resins are needed, there is no way around macroporous resins. Even relatively large contaminant molecules, such as NOM, can be adsorbed in the pores and are subsequently liberated during regeneration.

Macroporous, strongly basic anion-exchange resins based on a cross-linked polyacrylate can be tailored to exhibit a special pore structure and resin matrix. They are then ideally suited for the capture of high-molecular-weight compounds, for example, for the treatment and purification of products derived from biomass. This means that liquid sugar syrups or complex process solutions, such as fermentation broths, can be purified and treated. As an example, the naturally occurring glycosaminoglycan polymer heparin, which is used to prevent blood coagulation, can be extracted and thus purified with such a resin [*25, 26*].

Bead size. The particle size of monodispersed resins can be adjusted with high precision by means of continuous bead formation through a perforated plate. In aqueous suspensions containing monomer droplets of uniform size, the resin beads are then formed by means of polymerization (Figure 7). This method allows beads of different sizes to be created in a flexible and reproducible manner [*27, 28*].

To obtain ultrapure metals — ultimately through electrolytic separation — by means of hydrometallurgy, interfering foreign ions have to be removed right down to the trace level. This presents special requirements regarding selectivity, capacity and exchange speed. The size of the resin beads plays a key role here.

Macroporous resins with a sponge-like structure and a large inner surface area are usually employed here. The polymer beads in standard resin types measure between 0.5 and 0.7 mm in diameter. In addition to the type of functional groups in the polymer, their suitabil-

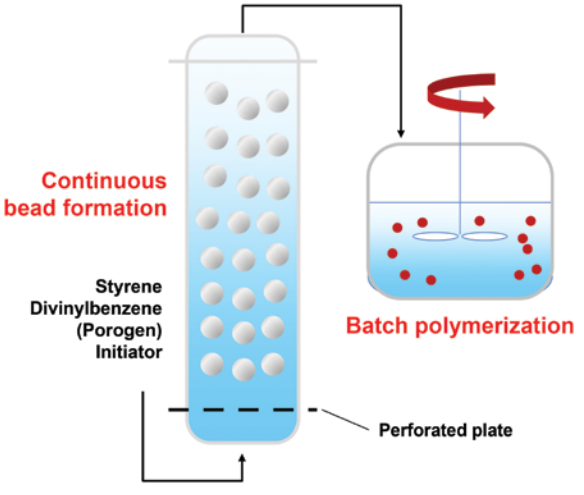

FIGURE 7. Monodispersed ion-exchange resins are produced by a two-stage process: continuous bead formation and subsequent batch polymerization

ity for a specific separation task depends on their number and a range of other properties and characteristics. Process parameters, such as the pH value, temperature and flowrate, also influence the separation performance.

Small resin beads (monodispersed small, MDS) with a diameter of just 0.3 to 0.4 mm exhibit very different properties and characteristics than standard-sized beads. Thanks to their smaller size and, in turn, shorter diffusion paths, they exhibit faster kinetics during exchange and regeneration. Their high packing density makes them ideal for chromatographic separation. They also have higher capacity utilization and, in turn, longer service lives with lower chemical requirements for regeneration. However, the higher packing density also results in greater pressure loss.

A comparison of the loading performance (Figure 8) of an iminodiacetic acid (IDA) chelating resin with MDS beads (left) with copper ions (blue) shows clear differences with respect to standard monodispersed resin (MD, middle) and heterodispersed resin (HD, right) with a wider grain size distribution. In addition to superior retention, the MDS resin exhibits a sharp, precisely defined limit zone of adsorption. This prevents a premature breakthrough observed especially with HD resin.

These beneficial properties can be leveraged for various tasks, such as lithium brine purification where small-size beads significantly reduce calcium. Ultrapure lithium brine obtained in this way is needed mainly for electrolysis in order to protect cell membranes from scale precipitation.

The resin-in-pulp (RIP) process [*29*] imposes quite different requirements with respect to bead size. In such a process, an ion-containing suspension of ore slurry is initially mixed with the resin beads. After a contact period during which the resin absorbs the ions, the resin is separated again. To increase efficiency, multiple vessels are positioned in a cascade arrangement, and the ore suspension is treated with the exchange resin in counterflow continuousRIP (cRIP; Figure

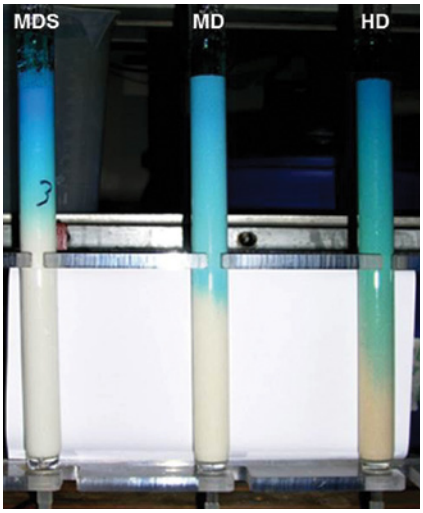

FIGURE 8. The photo shows the loading performance of three different cation-exchange resins with copper ions under identical reaction conditions: monodispersed small (MDS), monodispersed (MD) and heterodispersed (HD)

9). The RIP process is a useful alternative to fixed-bed ion exchange in columns. This is particularly advantageous when the substrate is a suspension or dispersion instead of a clear solution.

During this process, the majority of metal ions from the slurry are bound to the resin and can be separated from this when the resin is regenerated. In the field of hydrometallurgy, ion-exchange processes such as these are increasingly replacing the decanting of suspensions in large water tanks, because this not only requires a great deal of space, but is also extremely time- and cost-intensive.

Mechanically robust ion exchangers are needed for separating and transferring the resin as efficiently as possible. This helps prevent premature resin breakage during extraction. A sufficient size difference between resin and ore slurry particles is also essential for efficient separation. Because of this, monodispersed resins with a larger particle diameter of 0.85 mm (XL) and heterodispersed resins with an even larger average particle diameter of 1.1 mm (±0.1, XXL) have been developed (see Ref. 30 and 31 for XL resin type; and Ref. 32 and 33 for XXL resin type).

Lifecycle sequence. The ability to be regenerated is a key advantage of IEX resins over other materials that can just act as adsorbers and have to be disposed of after single use. In most cases, for example, when employed in softening or demineralization of water, in the preparation of makeup water or in condensate polishing in industrial water-steam circuits, IEX resins can be regenerated many times, resulting in a service life of several years.

There are, however, applications where regeneration may be inefficient or even disadvantageous. The former could be true in cases where the resin quantities employed are small and no on-site regeneration systems are available. If external regeneration is feasible, it should be decided on according to economic standards. Regeneration is usually also omitted in cases where only trace amounts of ions are removed from large volumes and the service life of the resin is therefore extremely long. This might be true for final polishing mixed-bed IEX systems in the production of ultrapure water. In this case, the original quality of the delivery form can no longer be restored, at least on site. For economic reasons, it therefore does not make sense to set up and maintain a regeneration unit.

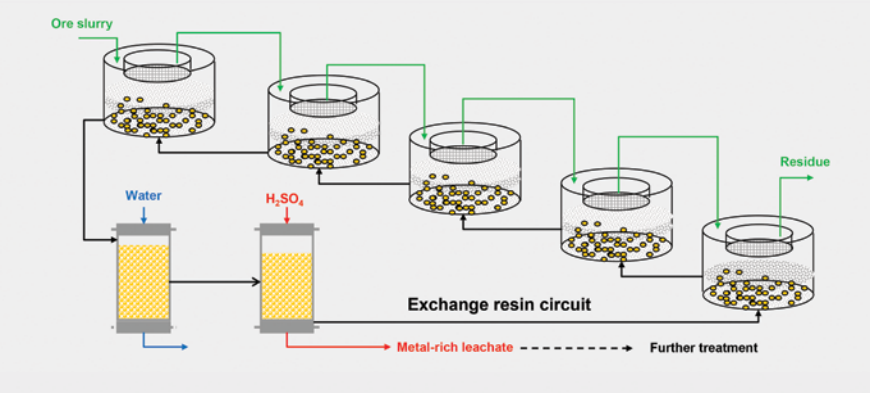

FIGURE 9. The continuous resin-in-pulp (cRIP) process is a useful alternative to fixed-bed ion-exchange columns

Regeneration may be disadvantageous when hazardous contaminants are bound to the IEX resin so that a significant concentration, that is volume reduction, of the hazardous waste has already taken place. If then the resin would be regenerated, a relatively small volume of resin would give rise to a larger volume of contaminated regeneration and washing solutions, which would have to be disposed of subsequently. This might be the case, for example, for resins loaded with mercury from fluegas scrubbing or with those loaded with radioactive cations from nuclear-power plants. In addition, such cations are bound very tightly, which would make regeneration impossible or at least not economical.

Innovative regeneration protocols, however, could help to recycle valuable resins even after loading hazardous substances onto them. One example is the regeneration of SBA resins which have been used to trap per- and polyfluoroalkyl substances (PFAS). In these cases, regeneration can be achieved by treatment with aqueous methanol containing a small amount of sodium chloride [*34*]. After regeneration, the resin can be reused and the methanol can be stripped off the regeneration solution, leaving behind only a very small amount of PFAS, salt and water.

Outlook

Although the basic principles of ion exchange facilitated by resins are known for more than a century now, the development is still ongoing. Improvements in selectivity, capacity and stability have been achieved over time and are likely to continue in the future. Not the least, future development will also be triggered by newly emerging, challenging fields of application. Improved recycling methods for spent battery materials, catalytic processes for the circular economy or advanced biomedical applications could be conceivable options. The industrial production of the first acrylate- and polystyrene-based resins from renewable feedstock or recyclates can be considered a milestone on the path to improved sustainability. The first representatives of this class of sustainable resins have just become available, not only in lab or pilot quantities [*35*], but on an industrial scale [*36*]. ■

Edited by Gerald Ondrey

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All figures courtesy of Lanxess Deutschland GmbH.

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Design Considerations for Steam-Heated Storage Tanks

Steam-heated storage tanks are critical to manufacturing processes, and prioritizing reliability in tank-system design and operations can mitigate unwanted issues

James R. Risko
TLV Corp (Ret.)

IN BRIEF

Storage tanks are essential to the chemical process industries (CPI), and they require significant capital investment to ensure optimal installation and continued reliable operation. Many of these storage tanks are heated by steam to maintain liquid viscosity or product integrity. The concept that storage tanks just maintain liquid stocks and are relatively simple equipment may confound some when dramatic issues occur (Figure 1). This article describes some specific issues the author has encountered at various chemical processing plants, and provides guidance for troubleshooting problems with steam-heated storage tanks.

Severe hammer in a tank coil

An example of a severe issue personally reviewed by the author was in the late 1980s regarding a large tank in a petroleum refinery in the northeastern U.S. It was only about three months before the issue occurred that the tank drainage problems were reviewed and discussed with the process engineer, who ultimately decided that the system was working "well enough." The specific issue at hand was that the condensate header-system backpressure had increased from 40 psig to over 60 psig, resulting in the electric condensate pump set (used for pumping the condensate into the return) ceasing to work. In a "cost-saving" effort, the engineer decided to bypass the pumping system and discharge the condensate directly into the highly pressurized condensate header.

FIGURE 1. Although storage tanks are common and critical equipment in the CPI, they can experience many significant issues

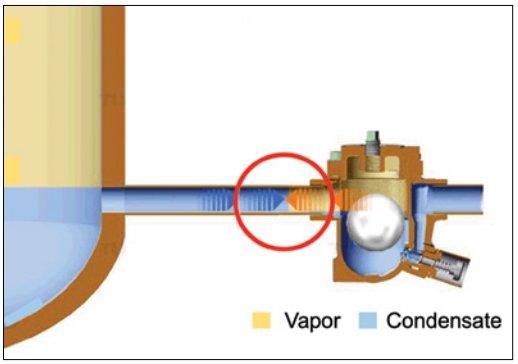

FIGURE 2. Vapor or steam locking of a steam trap can occur when there is a long horizontal run-up to the trap

Additionally, each steam-heating coil discharged directly through a straight horizontal line into the steam trap, with no drop-down into the trap. Discharging directly into a trap in such a manner can create a steam-lock condition. A steam lock will occur when the inlet piping to the steam trap is configured in such a way that steam vapor is somehow filling the steam-trap body and stifling — or even fully preventing — condensate from entering the trap. The result is that the trap locks shut until the steam in the trap body and inlet piping condenses (Figure 2) [*1*], allowing for condensate to finally enter the trap and be drained from the system.

While reviewing the bypassed system, it was noted that significant waterhammer occurred within the internal coils and also at the steam traps. Still, the site's process engineer remained unfazed by any concern about both items (Figure 3). Nevertheless, during each subsequent visit, the hammer was brought up with the engineer and subsequently dismissed because he felt that the system was "working."

That is, until about three

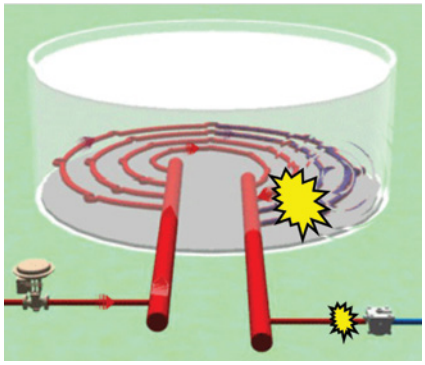

FIGURE 3. Hammer and coil damage experienced in internal steam coils can be the result of improper design

months later, when the engineer called and said he should have listened to the concern. Apparently, the hammer became so severe that it knocked one of the steam coils off its support and caused steam to leak directly into the stored liquid — making some of it boil and subsequently damage the tank top. According to the engineer, the tank had to be drained, the top repaired, insulation replaced, the tank pressure-tested and the test water treated at the sewage plant before final discharge. The exact cost was never provided, but the initial estimate of approximately $3,000,000 (circa 1988) is certainly memorable. Ultimately, the issues with the trapping and condensate system were corrected as originally recommended. A key takeaway from this experience is that if left unaddressed, hammer in a tank coil can lead to serious consequences and should be mitigated with high priority.

Steam coils in extreme cold

Another storage-tank problem reviewed was an asphalt storage tank in an extremely cold climate where thermal maintenance had been an ongoing issue. In this case, ascertaining the cause of the problem and its mitigation were relatively easy (Figure 4). There were three main issues related to the steam coils.

First, the coils were drained by subcooling, bimetal-style traps. They also discharged horizontally straight into the traps via a 2-in. line. Finally, a method was needed that could drain condensate in the event of loss of positive differential-steam pressure.

Bimetal traps can significantly subcool condensate by as much as 50 to 100°F, and can also cause difficulty with maintaining consistent high temperature [*2*]. Additionally, a long, straight horizontal run into the trap can cause a steam-lock condition, as previously explained (see Figure 2). Finally, positive steam-pressure differential is lost when a system shutdown occurs. This means that the coils can flood, lose temperature and corrode. If the temperature drops low enough, such as when the tank is empty, the coils can freeze and split if not fully drained.

Figure 5 shows the troubleshooting recommendations in a three-dimensional (3D) detail drawing. The bimetal traps were replaced with float and thermostatic traps that can discharge condensate without backup. Additionally, there is a vertical drop-down into the traps to

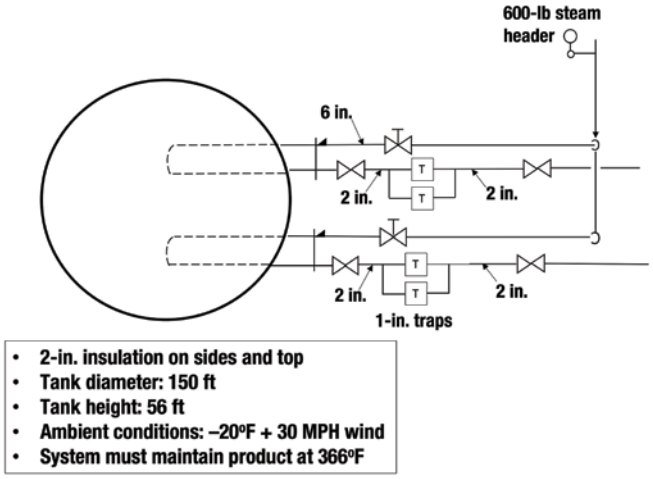

FIGURE 4. This asphalt tank was experiencing multiple hammer and control issues, even though the steam pressure was high

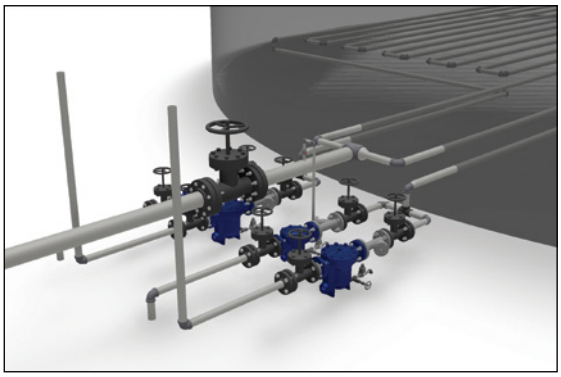

FIGURE 5. A 3D drawing can help installers better understand how to properly design pipe systems

allow for condensate to easily enter the trap body and mitigate against a steam-lock condition. In the drawing, it can also be seen that two of the traps (high-pressure models) discharge into the return line and two of the traps (lower-pressure versions) discharge to atmosphere.

The high steam pressure during normal operation prevents the lower-pressure traps from operating due to a pressure-block condition (thus preventing drainage). When the steam pressure drops into the rated operating range of the lower-pressure traps, they can open and discharge to atmosphere or grade.

This same dual high-pressure/low-pressure drainage design configuration can also be used with certain insertion-tank coils or shell-and-tube heat exchangers to mitigate corrosion (Figure 6). Because a rapid drop in steam pressure can cause the coils to go into vacuum conditions, a vacuum breaker is commonly recommended as shown.

Intermittent operation

Another issue encountered involved a steam heat exchanger in a petroleum refinery in the Caribbean where the tube set was corroding, requiring replacement every year or two. The process only needed to operate four hours per day, so during the "rest" period, the condensate was absorbing CO_2 and O_2, thus forming corrosive carbonic acid that rotted the coils. The use of a lower-pressure steam trap discharging to grade on shutdown was recommended to mitigate the corrosion.

Steam heaters and stall

Insertion-bayonet tube-side steam heaters (Figure 7) are essentially similar to steam shell-and-tube heat exchangers, which means that stall can be an issue that occurs when heat demand lessens [*3–6*]. As illustrated in Figure 8, when the steam pressure (red line) is higher than the backpressure (green line), the pressure differential is positive and only a steam trap is normally required for condensate drainage (purple triangle). When the steam pressure is negative (dark diagonal blue line intersecting the green backpressure line is beneath the green backpressure), the differential is negative and condensate can only be drained using a pump or pump-trap system (light blue triangle).

Stall is a condition where the steam pressure exiting the coil has become equal to or less than the backpressure of the condensate return system. When stall occurs, condensate backs up in the coil with various issues resulting, such as poor temperature control, corrosion or hammer.

A common solution to overcome the effects of stall is to incorporate a pumping system that discharges condensate into the higher backpressure system.

Another mitigation option is to drain condensate to atmosphere (where allowed, and if the condensate amount is small). In such instances, the combined high- and low-pressure trap arrangement can be used. However, it is mostly undesirable to discharge condensate to grade, so a pumping solution is needed.

Gravity drainage

Some insertion heaters may be at sufficient vertical height to enable gravity drainage of condensate into a trap and pump set or pump/trap system — this can be a benefit when possible. Gravity drainage is highly preferred, because anytime condensate remains backed up into a coil, its temperature can drop rapidly and significantly, making it acidic and corrosive in the process.

In the case of a steam trap and pump arrangement, if the heater condensate outlet is located high enough, condensate can drain into

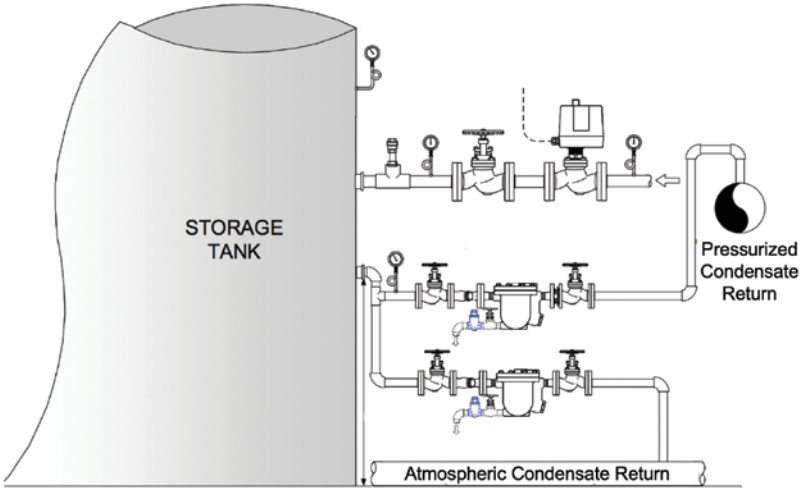

FIGURE 6. Designing for coil drainage on shutdown can be an important consideration

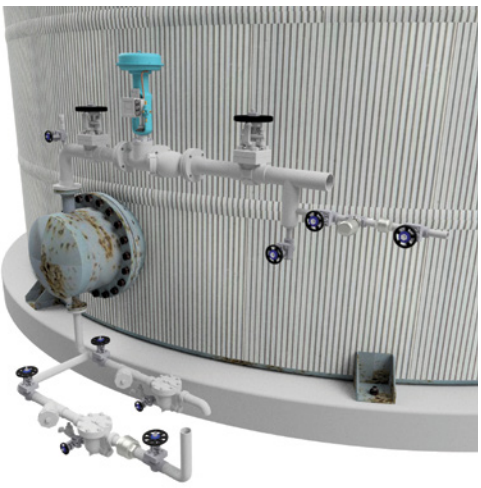

FIGURE 7. Bayonet heaters provide more filling head to the steam trap, but can present some other problems

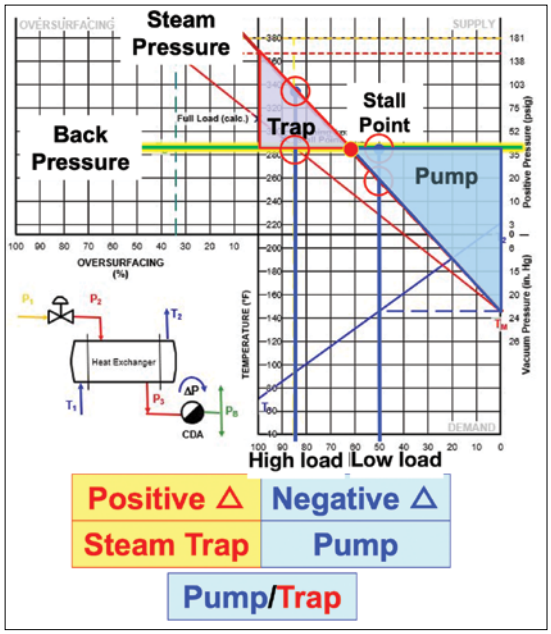

FIGURE 8. Condensate can drain from coils when the pressure differential is positive. Conversely, condensate can back up when the pressure differential is negative

the trap by gravity, which can then drain into the condensate-pump receiver by gravity [*7*]. Such systems must be carefully designed to enable gravity flow, otherwise a manometer effect can occur with the condensate and cause the coils to remain at least partially flooded. An arrangement with a steam trap and condensate pump is preferred when there are multiple coils in the tank, with each coil being drained through an individual steam trap and then collected and returned through a condensate pump set.

In some instances, the insertion-heater condensate outlet is not vertically high enough to enable full gravity flow into a trap and pump set. In such cases, a combination pump/trap system may be used, but a crucial point to note is that the insertion heater itself must have a tapping on the outlet side (just below the pass partition) to enable proper system balancing from the heater to the pump/trap's reservoir [*4*, *5*]. Without such a proper balance point, it is probable that the system will not drain freely and will not effectively fill the pump/trap reservoir, causing condensate to back up in the coil, which can lead to other problems.

In certain applications, thermosiphon effects from convection off of internal coils or bayonet heaters cannot provide the required circulation or temperature homogeneity throughout the tank liquid or on the wall. In such cases, a skin-heater system can be attached to the external tank wall, as shown by the blanket coils in Figure 9. However, unlike internally submerged coils, which have full surface-area contact with the stored liquid, only the surface area of the external coils that makes direct contact with the tank wall can be considered to conduct heat to the tank and stored fluid. This makes it essential to optimize the steam heat going into the external coils or skin heaters.

Figure 9 represents a graphic detail design provided to mitigate issues experienced at a refinery in a far northern location. Not only was the condensate drainage system inadequate, but the steam supply also experienced certain deficiencies.

Optimization for an external skin/blanket heater system starts with high-quality steam entering the coils. In this sense, many of the requirements for effective steam-heated air or process coils also apply. It may require that the steam traps installed in at least three drainage locations before the coils are functioning properly to mitigate large amounts of undrained condensate from reaching the coils. It may require that a

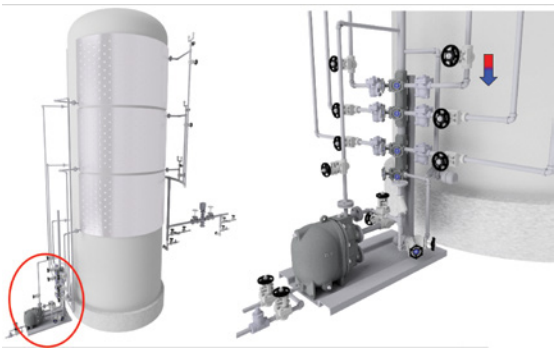

FIGURE 9. Skin heaters benefit when steam supply is optimized and condensate drainage avoids backup

FIGURE 10. Sulfur storage tanks require critical maintenance considerations to preclude serious issues

steam separator is used prior to the entrance of steam to the coils to optimize the heating capability on the coils' internal surface for most effective heat transfer. Commonly, a steam air vent can be incorporated at the entry point to remove as much air as possible before it enters the coil. Certainly, air-venting capability is prescribed at the coil exit if the heat quality is to be optimized. The mitigation recommendation for the northern refinery is shown on the steam inlet side in Figure 9 with vertical supply headers used in conjunction with proper steam trapping at the riser base to preclude large amounts of condensate reaching the coils during operation.

The tank was not particularly wide, the steam pressure not too high and the condensate loads relatively small, so this enabled an interesting opportunity for condensate drainage. Rather than requiring a large condensate vessel to handle flash steam, the condensate could be collected in a condensate manifold that was able to flash as required and supply condensate into the pump (Figure 9 red inset, expanded detail view on right).

Sulfur storage

Some storage tanks, such as those containing sulfur, can have severe thermal-maintenance requirements — not only for the sulfur itself, but also for the tank walls. For example, sulfur tanks can experience multiple issues aside from just sulfur freeze-up. They also have to keep the sulfur hot (around 275ºF) to keep it flowing and maintain approximately 260ºF for the walls and vapor space to mitigate against corrosion, sulfur buildup, pyrophoric FeS creation and fires or explosion [*8*]. To sustain critical internal liquid and wall temperatures, it is common to require high heat transfer, such as shown by the strap-on channel jacket-type heating elements on the outside of the tank, supplementing the heat supplied by the internal coils (Figure 10). ■

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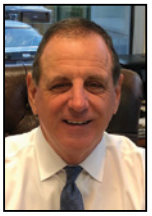

James R. Risko (Email: jimrisko@gmail.com; Phone: 704-641-8959) is the retired president of TLV Corp, Charlotte, NC, formerly responsible for U.S. and Canadian operations. He has 47 years of experience with steam systems, authored more than 60 technical articles, provided webinars to over 3,500 attendees globally and presented for numerous industry organizations and conferences, including the Kister Distillation Symposium, Distillation Experts Conclave, Fractionation Research Inc., AFPM, AIChE, the Ethylene Conference, RefComm, IPEIA, IETC, eChemExpo, AEE World and ASHRAE. He co-invented the world's first combination pump/trap and created the "Extended Stall Chart" for draining stalled coils, heat exchangers, and reboilers, the "Drop-down Loop Seal" concept to help mitigate hammer in vertical risers of flashing condensate lines and the 2-bolt combined steam trap strainer-connector. A past chairman of the FCI, he has been selected to receive its 2024 Lifetime Achievement Award. Risko is currently an Advisory Board member of both the Texas Industrial Efficiency Energy Program (TIEEP) and the TEES Industrial Energy Technology Conference (IETC).

A Holistic Approach to Asset Risk Management: Is it All or Nothing?

By combining mechanical integrity and reliability programs into a single framework, plants can streamline their asset maintenance strategies and mitigate all types of risk

Randy Montgomery
ABS Group

Asset maintenance first hit the headlines during the late 1980s when it became a target for efficiency improvements throughout the chemical process industries (CPI) globally. Initiatives at the time focused on traditional methods of improvement — reducing the numbers of staff and trying to work smarter with fewer resources. Despite these cuts, the pressure remained for asset managers to continue to reduce costs and increase efficiencies.

Has much changed? While much has certainly improved, the CPI are now faced with a new era in managing risk with scope to achieve far more. The benefits of combining mechanical integrity and reliability programs is a major approach for today's operators of capital-intensive, high-risk equipment and infrastructure. Those with experience in auditing, assessing and helping improve mechanical integrity (MI) and asset reliability programs have seen first-hand how organizations tend to develop and implement these two programs separately.

When the first process safety regulation was promulgated 30 years ago, it was understandable that many MI programs were developed as standalone systems. Also, with the asset-reliability improvement efforts over the past 10 to 15 years, there was reluctance to include MI activities and systems in the asset reliability programs. But the release of ISO 55000 Asset Management Standards and the increased implementation of ISO 55000 programs are now creating an industry-wide movement toward holistic asset-risk management.

A broader spectrum

MI and reliability programs can help to address a broad spectrum of asset risks, including operational, environmental and regulatory risks. There are also similarities between MI and reliability programs in how effective they are at identifying safety-critical equipment and asset criticality, as well as feeding into management systems and reliability business practices with the use of today's asset data and data management systems.

Typically, an organization's mechanical integrity program focuses on compliance with regulatory requirements, while their reliability program efforts focus on equipment reliability and maintenance efficiency. With few exceptions, most organizations do not combine MI and asset reliability programs to create a holistic asset management program.

There likely have been several motivations for maintaining and viewing these programs separately, such as the following:

- The desire or concern of regulator actions relative to combined programs (for instance, a regulator holding an organization accountable for reliability program activities)
- Seemingly competing objectives and goals of different organizational groups, specifically between the MI group and reliability group
- A potential understanding or viewpoint that regulatory and business-performance requirements need to be managed differently
- A lack of understanding of potential efficiencies and benefits of combining these two programs

FIGURE 1. An asset-management program that addresses a broad spectrum of risks — from pipeline leaks to high equipment vibration — can help organizations to better quantify their environmental, economic and safety risks

Defining the scope

The primary objective of both MI and reliability programs is to proactively perform asset maintenance activities to reduce the likelihood of asset failures, and the overall objectives are nearly identical. One of the primary differences, however, is the type and risk level addressed by these two programs. MI programs focus on managing high-consequence events impacting safety and the environment that occur at a lower frequency, while reliability programs focus on lower-consequence events (including economic events), which often happen at a higher frequency.

Some argue that these programs are managing different risks than those mentioned above, as well as some equipment failures. This may be true, but there is likely more commonality than often first realized. For example, the high vibration of a tower reflux pump (discovered via a reliability vibration-analysis program) may appear to be a reliability issue, but the unexpected failure of this pump could result in an over-pressurization of the tower and activation of a safety system, which many would classify as a process-safety near-miss.

Likewise, there are organizations that do not consider a leak (loss of containment) in piping as a reliability

issue. In reality, leaking equipment often results in downtime or other production impacts. Therefore, leaking equipment is unreliable equipment (Figure 1).

This concept of an asset-management program that addresses a broad spectrum of risks is not new and is provided in BS ISO 55000 series, Asset Management. One of the requirements of this ISO standard is to identify key stakeholders and then identify each group's risk. An obvious application of this requirement would be to include all safety risks (process and occupational), environmental risks, economic risks and other operational risks. This standard then outlines requirements for asset management programs that address all identified risks. Holistic asset management can begin by combining MI and reliability programs into a single framework.

Blending programs

Synergies between the two approaches relate to managing the risks associated with asset degradation and failures. There are also many synergies at the program-design, implementation and execution levels of these two programs. A key aspect of both programs is the implementation of management systems (the commonly used term in the process-safety world) or business processes (the commonly used term in the reliability world). Asset management systems define the overall asset management policies and objectives and the systems and processes needed (who, what and how) to implement the asset management policies and achieve the program objectives.

ISO 55001 addresses the elements of an asset management program (the "what") and ISO 55002 provides specifics regarding the "how" of the asset management program. Most holistic reliability programs include their management teams in core elements, such as work management, inventory management, equipment maintenance plans (such as predictive and preventive maintenance plans) and implementation of the computerized maintenance-management system (CMMS).

So what are the common attributes between ISO-55000, MI and reliability-program management systems? Looking at Table 1, it can be seen how plants can leverage and integrate activities from these three programs with a few examples of the common elements from each of these three programs. While the strategic and conceptual similarities between reliability and MI programs are interesting, the important synergies are related to the tactical activities that influence the day-to-day implementation of these two programs.

Synergizing examples

Considering the example of a process pump in hazardous chemical service, two potential areas of synergy between asset reliability and MI activities include common reliability activities, such as operator walks (visual inspection) and vibration analysis. Both of these practices are also MI-related activities because they help to detect and prevent loss-of-containment events. Another example is instrumentation and control-system reliability practices, such as periodic sensor calibration and functional checks. When these practices are applied to safety-critical instruments and controls (such as safety instrumented systems), MI requirements are incorporated.

The common MI practices for fixed equipment, such as a shell-and-tube heat exchanger or pressure vessel, would include API-type inspections and testing, including visual inspection and pressure boundary-thickness non-destructive testing (NDT). Leaks in a heat exchanger or pressure vessels during operation can result in unplanned downtime (which is a reliability impact). Also, these API inspections and tests help predict the end-of-life for these equipment items, which allows for planning and proactive equipment replacement (which is a reliability issue). There are also common reliability practices related to managing the condition of heat-exchange fluids (such as cooling water) and the periodic cleaning of heat-exchange surfaces. These activities can reduce thinning and degradation of the shell and tube and lower the probability of a process safety event, such as loss of containment.

Asset data

A key area between MI and reliability programs is asset data management, where both programs require compilation, verification and management of asset data to be effective. This data-management effort involves developing a master asset list and then populating this list with relevant asset-related data.

Master asset lists typically involve the following elements:

1. Reviewing the piping and instrumentation diagrams (P&IDs) to identify assets
2. Compiling asset information from engineering, maintenance and operational files and records
3. Performing field walk-downs to verify the asset list and collecting missing data
4. Establishing the master asset list and data in the data-management systems
5. Organizing and associating the relevant data (including drawings and documents from original equipment manufacturers) in the data-management systems

While the steps for developing the master asset management list for MI and reliability purposes are similar, each program has slightly different

TABLE 1. TYPICAL COMMON ELEMENTS OF ISO 55000, RELIABILITY AND MI PROGRAMS

ISO 55000	Reliability program	MI program
Asset management objectives (ISO 55002 - 6.2.1 [3])	Asset performance; lifecycle costs; health, safety and environment	Health, safety and environment
Asset portfolio	Master asset list	MI-covered equipment LL
Asset information (ISO 55002 — Section 7.5 [3])	Asset records	Equipment process-safety information
Asset management plan — Operational and maintenance plans (ISO 55002 — Section 6.2.2 [3])	Reliability strategy	Inspection and test plans
Corrective actions: both short- and long-term corrections (ISO 55002 — Section 9.2.2.1 and 10.2.1 [3])	Work management	Equipment deficiency management

data needs and sources based on equipment type.

In addition to the slightly different data needs for MI and reliability programs, two data-management systems are typically needed to store the asset data and manage the programs. These two systems are the CMMS and the inspection data management system (IDMS).

While these two data-management systems have many similar attributes, they are used for different purposes and operate differently. The CMMS is a software application that helps maintenance organizations manage their maintenance activities in one place. The CMMS provides a platform to manage the data around site maintenance, repair and operations (MRO), including preventative, predictive and reactive maintenance.

Having accurate and complete asset data is crucial to building a CMMS, not to mention having the ability of the CMMS to communicate with other software systems within the organization, including the IDMS. The CMMS system also serves as a repository for implementing, executing and improving maintenance work processes (work, asset lifecycle, MRO inventory and so on), which drive the activities and dictate how maintenance is performed.

The IDMS is used to track and manage asset condition over time to determine future inspection and testing schedules. The software system uses equipment condition assessments (for instance, thickness data) to calculate rates of degradation (such as corrosion) to assess the expected remaining life of the asset before failure. Additionally, the IDMS can be used to calculate the current and future risk of assets in order to optimize inspection and test plans, including risk-based inspection (RBI). These inspection and test plans (including the type of activity and due date) are sent to the CMMS for scheduling and execution planning. This transfer of information is either performed manually (meaning plans are manually transferred from one system to another) or digitally (where information is automatically transferred).

When inspection and testing results are uploaded to the IDMS, recommendations that require corrective actions to resolve equipment deficiencies are sent to the CMMS via work order for execution and tracking, and then ideally the CMMS communicates back to the IDMS when the action is completed to satisfy regulatory recording requirements.

Motivating a change in mindset

Organizations that do combine their MI and reliability programs typically achieve tangible and intangible benefits. The tangible benefits relate to efficiencies in asset cost and programs, described in the following sections.

Reducing unplanned downtime. Implementing both MI and reliability asset management plans and executing the plans as scheduled reduces both losses of containment and functional asset failures

Reducing planned downtime. Both MI and reliability asset plans include the implementation of activities related to assessing asset condition, such as thickness monitoring (MI-related activity) and vibration monitoring (reliability-related activity). Once implemented, these types of activities reduce the need for intrusive activities (which then require assets to be offline), and help to predict capital and operational expenses associated with asset replacement.

Program efficiencies. Combining programs reduces the level of effort needed to develop and maintain program operational activities, such as asset lists, maintenance work instructions, asset management plan execution, asset deficiency process and so on. The use of different work processes and data systems to operate the MI and reliability programs results in duplicated efforts.

In terms of intangible benefits, there are also several organizational and cultural benefits, as described below.

Program confidence. A combined program provides the key organizational stakeholders (for example, plant management, executive management) with more confidence that

regulatory compliance requirements are being met; asset-failure risks are being managed; and holistic asset conditions are known and being managed.

Program view. Creating a "single source" of the asset integrity and reliability provides program executors, plant management, and executive management with a single view of the asset management program.

Improved program direction. Combining the programs can reduce confusion about which system needs to be followed and provides clear, unified expectations for the asset management program.

The bottom line is that combining the MI and reliability programs can reduce the cost of asset maintenance and help reduce the perception that the MI program is only a cost. Also, the intangible benefits allow organizations to move from viewing the MI program as a burden to the view that both programs make business sense.

Tomorrow's view

The safety we expect in our everyday lives depends on things working — and working properly. From the offshore rig drilling for oil, the processes used for refining petroleum, to the power stations and plants near our homes, all must be built, operated and managed with risk and safety in mind. Society in general is becoming less tolerant of preventable incidents causing harm or death, or incidents leading to environmental degradation.

Companies need to be able to also make high-confidence asset-integrity decisions, enabling them to increase the profitability and productivity of the asset base while minimizing the exposure to the risk of catastrophic events. Failure to do so will allow competitors to gain a significant lead with regulators, financial markets, stakeholders and profitability. In the future when things go wrong, questions will be asked — and in contrast to the past, it is likely that there will be a requirement for greater accountability of individuals and organizations and transparency on their processes.

Taking a holistic view of risk and the management of physical assets, including selection, maintenance, inspection and renewal, plays a key role in determining operational performance, safety and profitability. ■

Edited by Mary Page Bailey

Author

Randy Montgomery is the senior director of oil, gas and chemical services at ABS Group (1701 City Plaza Drive, Spring, TX 77389; Website: www.abs-group.com). He has more than 30 years of experience in reliability, maintenance, integrity management, process safety, operations and process engineering, including 13 years of industrial experience. His responsibilities at ABS Group include identifying, developing and delivering technical solutions to help industry clients preserve their right to operate and improve their return on investment. He is a co-author of the Center for Chemical Process Safety's Guidelines for Effective Mechanical Integrity Programs and has coauthored several technical papers in the field of maintenance and reliability. Montgomery holds a B.S.Ch.E. from the University of Cincinnati.

The 34th edition of Achema, World Forum and Trade show for the process industries, takes place June 10–14 at the fairgrounds of Frankfurt am Main, Germany (www.achema.de). More than 2,700 exhibitors from over 50 countries will be presenting a diverse range of innovations and products across twelve exhibition groups and a Special Show Hydrogen. With more than 1,000 speakers, the accompanying congress and stage program also runs throughout the week.

"Achema once again emphasizes its role as a central platform and meeting place for all stakeholders in the process industry," says Björn Mathes, CEO of Dechema Ausstellungs-GmbH. "With a notable surge in exhibitors and one of the most diverse lecture program in recent Achema history, this year's event also offers an unparalleled opportunity for young technical and scientific talent," he says.

For those unable to attend the fair, *Chemical Engineering* will again co-produce the *Achema Daily*, which will be updated and published each day of the show — both online and delivered at the entrances of the halls — bringing you up to date on the activities at the fair and the products being exhibited. A small sample of some of these products are presented here.

Two-stage drying process nearly halves energy consumption

With its two-stage drying process (photo), this company has transformed traditional drying methods, leading to a significant reduction of 45% in heating energy consumption. This groundbreaking technology has revolutionized waste management practices, making them more sustainable and efficient, the company says. The process capitalizes on the principle of multiple-effect evaporation commonly used in evaporation technology. By operating under vacuum conditions in stage 1 and atmospheric conditions in stage 2, this process enables a lower evaporation temperature in stage 1, resulting in considerable energy savings. One of the key advantages of this innovative design is the recovery of energy, released during condensation in stage 2. This energy is then utilized to heat stage 1. Optimal performance is achieved by applying products in a thin film on the heated wall. This approach not only enhances the effectiveness of the drying process, but also makes it suitable for various applications, including the drying of sewage sludge. Hall 4, Stand B24 — *Buss-SMS-Canzler GmbH, Butzbach, Germany*
www.sms-vt.com

A pump for corrosive and abrasive media

This company is showcasing its standardized chemical pump (HPN series; photo) according to ISO 2858, which is based on its experience with the HPK series. As with the HPK series, all media-contacting wear parts in the chemical standardized pump are coated with a special polyurethane, known under the brand name APFlex, which offers not only high wear protection, but also improved resistance to aggressive chemicals. These special polyurethane blends are in-house developments, proving to be resistant to water absorption due to their polymer structure. The APFlex lining of the pumps is, depending on the size, suitable for extreme stress in abrasive or corrosive areas with scatter grain up to 10 mm. The chemical standardized pump is resistant to processing oils and has a temperature resistance of up to 95°C. The delivery rate is between 15 and 400 m^3/h. Hall 8, Stand F52 — *Habermann Aurum Pumpen GmbH, Bochum, Germany*
www.habermann-aurum-pumpen.de

Intrinsically safe devices for the chemical process industries

This company is exhibiting its explosion-proof mobile devices and solutions, such as the new 10.1- in. Windows and Android tablet IS940.1/IS945.1, the 5G radio IS440.1, the RealWear Navigator Z1, the 5G smartphone IS540.x, the industrial smartwatch IS-SW1.1 and the Inspection System Valve Sense IS-VS1A.1 (photo). The new IS940.1/IS945.1 tablet has been designed for data communication in the process industry and in automation to

ACHEMA 2024
Frankfurt / Main
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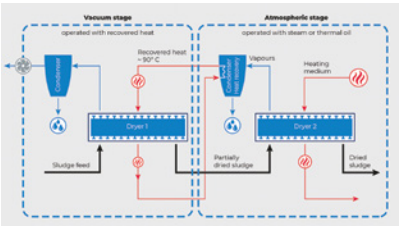


Buss-SMS-Canzler

Habermann Aurum Pumpen

i.safe Mobile

Linde Material Handling

integrate seamlessly into the existing system landscape with 4G/5G campus or Wi-Fi network. The tablet is equipped with an IIoT-optimized chipset, including a 16-pin ISM interface, Wi-Fi 6, Bluetooth 5.2 and NFC support, and has a replaceable, long-lasting battery, freely programmable buttons and main and front cameras. The new RealWear Navigator Z1 is an intrinsically safe head-mounted wearable with intuitive voice control for completely hands-free operation during remote training and support, field service management tasks and site inspections, even in noisy environments of up to 100 dBA. Hall 11.1, Stand B26 — *i.safe Mobile GmbH, Lauda-Koenigshofen, Germany*
www.isafe-mobile.com

Electric pallet trucks for use in ATEX zones

The introduction of the T16 EX to T20 EX series (photo) marks the debut of new compact pedestrian pallet trucks on the market. Featuring a robust chassis and reinforced forks, they are designed for loads of up to 2 tons. The models are available in the 2G/2D and 3G/3D equipment categories for ATEX zones 1/21 and 2/22. The narrow design, tight turning radius and intuitive steering and controls make the trucks quick and easy to maneuver in confined spaces. Explosion-protection measures include ignition protection against electrical and mechanical sparks, continuous temperature monitoring of relevant components and precautions to prevent electrostatic charging. Another new product available for explosion-protected counterbalanced trucks is the artificial intelligence (AI)-based Reverse Assist Camera system. It identifies people to the rear of the truck and alerts drivers of potential collisions. Hall 4.1, Stand G13 — *Linde Material Handling GmbH, Aschaffenburg, Germany*
www.linde-mh.de

ystral gmbh maschinenbau +processtechnik

Wet and disperse powders with this new machine

The Coflow continuously operating powder wetting and dispersing machine (photo) is designed for a wide range of applications in various industries. In the Coflow, solids and liquid components are introduced in controlled quantities via solids dosing units or a liquid pump, and combined in a premixing zone with an oblique blade agitator. Fine dispersion then takes place using a rotor-stator system, whereby the stator can be designed with different slot widths depending on the application. An inducer installed between the premixing zone and the rotor-stator zone effectuates a pressure increase. This change in pressure causes the air brought in with the powder to be separated, resulting in a lower residual air content in the product, the company says. For the market launch at Achema, the Coflow is available in the size Coflow-4 for production with a total capacity of 6,000–13,500 kg/h. The size Coflow-3 is currently under development and, with a total capacity of 2,000–8,000 kg/h, is suitable for small-scale production and for use in pilot plants and technical training centers. Hall 6.0, Stand B49 — *ystral gmbh maschinenbau + processtechnik, Ballrechten-Dottingen, Germany*
www.ystral.de

ABB

Three decades of FTIR spectroscopy development

First manufactured 30 years ago in Frankfurt, this multi-component emission monitoring system using Fourier-transform infrared (FTIR) spectroscopy system is now in its fourth generation. The gas analyzer simultaneously measures up to 15 components in exhaust gases from industrial chimneys in chemical plants, waste incinerators, cement kilns and more. The ACF5000 (photo) is designed to expand the system's functions, adjusting to users' changing needs. When new components become mandatory to measure or emission limits change, the ACF5000 can be adjusted by a mere software upgrade. The high-resolution FTIR spectrometer provides selective measurement of IR-active gas molecules with high sensitivity and stability. The FTIR measurement principle ensures that the spectrometer is free from drift and does not require frequent adjustments. Hall 11.1, Stand E62 — *ABB AG, Mannheim, Germany*
www.abb.com

A magnetic drive for large-scale bioreactors and more

This company has developed a new type of magnetic drive (photo), which it has applied in bioreactors with volumes up to 20,000 L. The comparative advantage of this drive over traditional magnetic drives is

Bioreactors.net

its relatively easy scalability of construction, convenient installation and maintenance. Its potential application is not only limited to bioreactors but also extends to mixing in other sterile processes. The principle of the drive is based on magnetic rotors mounted in mixers rotating around a stationary tube. Inside the tube are magnetic rotors with driving magnets, while on the outside of the tube, in the mixer, are mounted driven magnets. The rotational coupling of the mixer around the stationary tube is ensured with the help of SiC and ZrO_2 bushings. Hall 12.0, Stand A4 — *Bioreactors.net Ltd., Riga, Latvia*
www.bioreactors.net

A high-capacity gas turbine for gas-mixing applications

The Orion (photo) is a self-inducing impeller for internal gas recirculation from the head space back into the liquid. The gas turbine is designed to maximize the productivity of high-capacity gas/liquid reactors. Low lifecycle costs and an excellent return on investment are just two of the benefits. Gas-inducing impellers increase the utilization of pure gases during gas-liquid or gas-liquid-solid multiphase-type reactions. Due to the internal gas recirculation, an external loop is not required, resulting in lower investment costs and increased safety in case of hazardous gases. The inner geometry of the Orion is flow optimized to reduce pressure loss of the recirculated gas and thus, increasing the amount of recycled gas. Hall 6.0 Stand C19 — *Ekato Rühr- und Mischtechnik GmbH, Schopfheim, Germany*
www.ekato.com

Ekato Rühr-und Mischtechnik

Enhanced multifunctional mass flowmeters/controllers

Building upon the success of its Flexi-Flow Compact series (photo, p. 42), this company presents an extensive line extension, offering unparalleled versatility and precision in gas flow measurement and control. The latest iteration of the Flexi-Flow Compact series introduces a range of innovative models and features, including instruments tailored for lower flow ranges starting at 0–5 mL/min. Additionally, the series now includes down-ported instruments for applications where top-mount installation is required, and flow controllers equipped with integrated shut-off valves to provide a higher degree of leak tightness or enable emergency shut-off. One of the key enhancements is the incorporation of EtherNet communication, providing

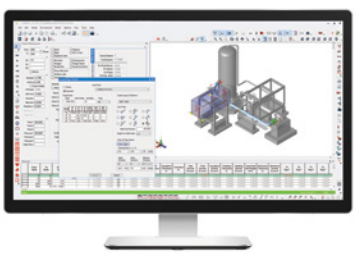
Bronkhorst High-Tech

seamless connectivity and integration capabilities for modern industrial environments. The advanced sensor technology ensures not only stable flow control, but also rapid response times, with settling times smaller than 150 ms, facilitating precise control even in dynamic process conditions. Hall 11.1, Stand F3 — *Bronkhorst High-Tech B.V., Ruurlo, the Netherlands*
www.bronkhorst.com

A 3D-printed containment shroud for mag-drive pumps

One of the technical highlights of this company is the new 3D-printed containment shroud for magnetic-drive (mag-drive) pumps of the Magnochem type series. Named Magno-Protect (photo), the component offers the same safety as a double-walled containment shroud — without the latter's disadvantages of heating up strongly and having high eddy-current losses. While providing comparable safety, the overall efficiencies of the new mag-drive designs exceed those of canned motor pumps. Designed with a structure of channels, the new containment shroud offers a second, redundant, static safety barrier preventing leakage of the fluid handled. A pressure transmitter monitors the vacuum generated, which is present during normal operation in the channels of the containment shroud. If the monitored pressure rises to atmospheric pressure, the outer containment shell is leaking. If the pressure rises above the ambient pressure, the inner containment shell is damaged. Hall 8.0, Stand H14 — *KSB SE & Co. KGaA, Frankenthal, Germany*
www.ksb.com

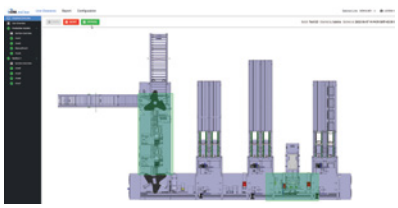
KSB



Hexagon (intergraph PP&M Deutschland)

Software enhances piping analysis and hydrogen-readiness

CAESAR II Version 14 (photo) is the latest iteration of this company's pipe flexibility and stress analysis software. CAESAR II enables quick and accurate analysis of piping systems subjected to a wide range of loads, considering weight, pressure, thermal, seismic and other static and dynamic conditions. It can perform analysis for all types of piping stress calculations in several environments, such as buried, on ground and submerged in water. A key addition of this new release is the support for hydrogen piping and pipelines with the inclusion of code ASME B31.12. Amid rapid growth in hydrogen production worldwide, this inclusion aims to ensure that engineers can take on hydrogen projects with confidence. Other enhancements include: the possibility to manage wind and seismic conditions with ease using ASCE 7-2022 and IBC-2021 editions; the update of popular European code EN 13480-3:2017/A5:2022 — Metallic industrial piping — Part 3: Design and calculation; and more. Hall 11.0, Stand D59 — *Hexagon (Intergraph PP&M Deutschland GmbH), Garching near Munich, Germany*
www.hexagon.com



CIM Industrial Systems

This software shortens batch changeover times

Deep learning technology dramatically helps shorten batch changeover times, while also mitigating some of the inherent weaknesses of current line-clearance procedures. Checking production lines for rogue components and documenting the process often takes over an hour. And despite detailed standard operating procedures (SOPs) and checklists, there is always a risk of human errors. A new solution for camera-assisted line clearance offers pharmaceutical manufacturers a helping hand by reducing the time spent on manual inspection and documentation. The solution for assisted line clearance builds on this company's fully validated GAMP Cat. 4 vision software (photo). Using deep-learning models for object and anomaly detection, it takes operators through a simple three-step process, while logging every action taken along the way. Hall 3.1, Stand E97a — *CIM Industrial Systems A/S, Viby, Denmark*
www.cim.as

Smart control valve for minimal flowrates and high pressures

Low-flow valves or needle valves are always used wherever minimal flowrates or high pressures have to be controlled with particular precision or securely shut off. With the type 7042 (photo, p. 43), this company has now developed a low-flow valve that not only offers minimal K_V values of 0.0027 to 1.7 and a nominal pressure of PN320, but also impresses with

state-of-the-art field integration. The 7042 shows its full potential together with the optionally integrated positioner type 8049. In addition to an explosion-protected and FM version, it can also be equipped with an IO-Link connection or industrial internet of things (IIoT) module. With IO-link, a single cable with an M12 plug bundles the positioning signal, position feedback, data transmission and even the power supply. The continuous monitoring of the status data allows even the slightest irregularities in the control behavior to be detected. Hall 11.1, Stand E45 — *Schubert & Salzer Control Systems GmbH, Ingolstadt, Germany*
controlsystems.schubert-salzer.com

Schubert & Salzer Control Systems

A system for automated laboratory reactors

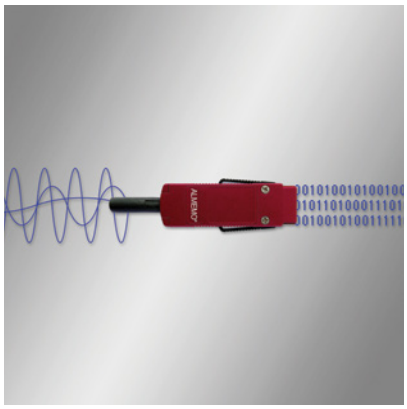
The LabVision system (photo) combines the flexible LabVision software for centralized data acquisition, automation and complete documentation of experiments with the LabBox and LabManager interface devices, to which existing laboratory equipment can be connected. This groundbreaking development represents a significant advance in chemical synthesis and process optimization and is specifically designed to revolutionize research and development departments worldwide. The compact and user-friendly system is designed to maximize laboratory efficiency and improve the reproducibility of experiments, enabling researchers to perform complex chemical reactions with the highest precision and speed. Hall 12.0, Stand D115 — *HiTec Zang GmbH, Aachen, Germany*
www.hitec-zang.de

HiTec Zang

Ammonia sampler improves sampling safety and accuracy

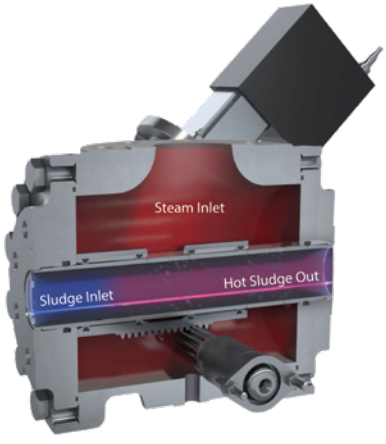
Anhydrous ammonia is used in the production of fertilizers, plastics, textiles, petroleum and more. To avoid ammonia-stress-corrosion cracking in storage tanks and product quality concerns, the product must be regularly sampled to verify a water content of 0.2 to 0.5%. This company's ammonia sampler (photo) has been specifically designed to address the issues inherent to manual sampling by utilizing closed-sample fixtures that improve safety by limiting operator exposure and minimizing environmental impact from excess

Swagelok Company



Ahlborn Mess- und Regelungstechnik

Teledyne Gas & Flame Detection



Hydro Thermal Europe

emissions. It also employs residue tubes that are pre-chilled using the cold ammonia itself, thus preventing aggressive boiling that threatens fill accuracy. The system also has features that help to control the dispensing of the ammonia sample and ensure a consistent sample size. Other features include a single handle for easier operation and reduced operator error and a touchscreen interface to control all heater operations. Hall 8, Stand C77 — *Swagelok Company, Solon, Ohio*
www.swagelok.com

Intelligent connectors are changing sensor technology

More powerful microprocessors have made it possible to create completely self-sufficient digital sensors that function like a measuring device themselves. The intelligence of the digital sensors is located in the connector plug. In addition to the additional flexibility of a digital sensor, individual sensor parameters, such as linearization, scaling, attenuation, averaging, measuring rate or longer comments can also be stored in the intelligent Almemo D7 and D6 connectors (photo) for clear assignment of the sensors to the measuring stations. The digitization of sensors — even those from other vendors — makes it possible to consider the measuring device and sensor separately during a traceable initial calibration or recalibration. The device itself no longer needs to be taken into account during calibration. Each digital sensor with an D7 or D6 connector forms a self-contained, calibratable measuring chain. This means that the sensors can be calibrated independently of the measuring system. Hall 11.1, Stand B64 — *Ahlborn Mess- und Regelungstechnik GmbH, Holzkirchen, Germany*
www.ahlborn.com

Dedicated IR sensor for reliable methane detection

The OLCT 100 XPIR (explosion-proof IR) fixed-gas detector (photo) is a new infrared (IR) sensor that brings the advantages of stable and reliable methane-detection measurements to the industrial, utility and laboratory markets. Designed for the company's highly popular OLCT 100 XPIR fixed gas detector, the IR sensor ensures measurement stability and is impervious to catalytic poisons. Moreover, the device offers a long lifespan, even with the presence of background gas, to deliver 100% lower-explosive-limit (LEL) methane detection. The IR methane sensors deploy two IR wavelengths: one active wavelength for gas absorption and one providing a reference wavelength to compensate for the impact of temperature and humidity. Because IR sensors do not require O_2 to operate, these sensors are also suitable for use in 0–100 vol.% methane-gas environments. The ATEX-approved OLCT 100 XPIR comes with 4–20-mA output. Hall 11.1, Stand E55 — *Teledyne Gas & Flame Detection, Arras, France*
teledynegasanflamedetection.com

This heating system is designed for unrestricted flow

This company offers on-demand steam-injection fluid-heating, cooking and processing systems. These heating systems are said to be the most reliable, durable solution for heating water and slurries with instant and precise temperature control. The company's newest innovation is the Non-Obstructing Heater (NOH; photo). The NOH's straight-tube design allows for unrestricted flow, prevents pressure drop and heats slurries without plugging or fouling. In addition, the NOH's rugged design and construction materials enable it to handle viscous slurries, particulate-matter-filled products, abrasive and corrosive substances and stringy products, as well as enables inline water heating abilities. Compared to other heating systems, the NOH utilizes a smaller footprint, with direct installation into the existing system piping, and does not require special tools for maintenance. Sizes range from 2 to 12 in. (DN50–DN300), with volume capabilities reach 6,900 gal/min (up to 1,567.2 m^3/h). Hall 6.1, Stand A100 — *Hydro Thermal Europe Corp., Lyon, France*
www.hydro-thermal.com ■

Gerald Ondrey

From water to waste management, IFAT 2024 Munich (May 13–17) offers visitors insights and innovative solutions on a wide range of topics in the field of environmental technologies. From recycling methods and digitization strategies to material-flow management, the focus is on opportunities and challenges for industries, municipalities and public authorities. In addition to the more than 3,300 exhibitors in 18 halls, the program at IFAT is both highly varied and highly specialized. The Green Stage is the central point for exhibitors, start-ups and cross-industry topics. The Blue Stage focuses on water, sustainable and climate-adapted water management, water reuse and energy-efficient wastewater treatment plants. The Orange Stage highlights circular economy and resource efficiency, material-flow management, as well as municipal technology and waste management. The Spotlight Areas focus on one topic: plastics and battery recycling, hydrogen in the circular economy or the digitalization of water management.

The following is a small selection of some of the products being exhibited at IFAT Munich.

Total solids measurement on primary sludge

The MicroPolar LB 566 measuring system (photo) determines the total solids content of sludge, which facilitates the calculation and optimizes the use of polymers and flocculants. During further thickening of the sludge, flocculants are added to the process, which leads to optimized dewatering grades. The LB 566 is a microwave transmitter that measures reliably the dry matter content and offers excellent accuracy. Representative measurement results are achieved due to the fact that the entire material flow in the pipeline is detected, even for large pipeline diameters. Hall C1, Stand 511 — *Berthold Technologies GmbH & Co. KG, Bad Wildbad, Germany*
www.berthold.com

Blowers and compressors for water-treatment applications

The robust construction of TYR WT rotary lobe blowers (photo) offers outstanding reliability and longevity, which is important in the harsh environment of the water and wastewater sector. The TYR's constant air flow of the blower ensures steady pressure, which is essential for the aeration of clarifying tanks. With integrated inlet and outlet silencers that reduce noise levels, the TYR WT ensures quiet operation. Maintenance is limited to belt tension inspection, filter and transmission oil replacement. Also exhibited are the MINK MM claw compressors, which are designed for a wide range of industrial applications with overpressure of up to 2.0 bar(g), making them suitable for aeration, filtering out sand in the sand trap and biogas circulation in wastewater treatment. Thanks to dry and contact-free compression, no oil is required in the compression chamber, which reduces maintenance intervals and thus operating costs. The Aqua version of the MINK MM has a special coating that prevents corrosion. This is particularly useful in humid environments. There are also other versions that are ATEX certified and can therefore be used safely in potentially explosive areas. Hall B2, Stand 127/226 — *Busch Vacuum Solutions, Maulburg, Germany*
www.buschvacuum.com

Plastics recycling made easier with this pellet mill

In addition to the production of substitute fuels and wood pellets, the flat die pellet mill Type 45-1000 (photo) also processes large-volume plastic waste into compact, dosable pellets, which can then be fed into a chemical recycling process. By recycling plastics in line with the circular economy, companies not only conserve fossil resources but also reduce CO_2 emissions. Used textiles can also be prepared for recycling by means of pelletization, and used tires by means of granulation. The company's plants also meet the increasing demand for pelleted sewage sludge. In the form of sewage sludge pellets, this organic waste product can be transported dust-free, safely and cost-effectively to where it is needed. Sewage sludge pellets are mainly used for thermal recovery. Another focus of interest is shifting to sewage sludge and sewage sludge ash, par-

Berthold Technologies

Busch Vacuum Solutions

Amandus Kahl

WTA Unisol

Endress+Hauser (Deutschland)

AUMA Riester

Buss-SMS-Canzler

ticularly for the recovery of phosphorus for use in fertilizer production. Hall B4, Stand 317 — *Amandus Kahl GmbH & Co. KG, Reinbek, Germany*
www.akahl.com

New membrane modules for wastewater treatment

The new Mytex H5L membrane bioreactor (MBR) module series has a wide range of membrane surface areas (from 20 to 1,300 m^2), thus providing access to 80,000 different immersed membrane modules. Like all products in the Mytex series, the new Mytex H5L modules (photo) are characterized by the highest flexibility in terms of size and operation. They are particularly suitable for plants with an inflow of more than 1,000 m^3/d. The modules have been produced free of per- and polyfluoroalkyl substances (PFAS) to ensure that no harmful substances are additionally introduced into the water. The highly advanced membrane sheets of Mytex are used in a variety of applications, from the food-and-beverage industry to water treatment and wastewater recycling. Hall A2, Stand 140 — *WTA Unisol GmbH, Gotha, Germany*
www.wta-unisol.com

Measure many parameters with this compact spectrometer

The Memosens Wave CAS80E spectrometer (photo) offers reliable real-time measurements of relevant analytical parameters, such as chemical and biological oxygen demand (COD, BOD), turbidity, nitrate and spectral absorption coefficient (SAC) in one single device. The compact CAS80E is easy to install and maintain and ensures reliable, interference-free communication thanks to Memosens digital technology. The device is suitable for measuring a wide range of analytical parameters in: drinking water, surface water, wastewater and utilities. By operating directly in the process, the spectrometer ensures uninterrupted measurements in real time. The spectrometer is quickly adapted to the specific application through pre-installed analysis models. Hall C1, Stand 451/550 — *Endress+Hauser (Deutschland) GmbH & Co. KG, Weil am Rhein, Germany*
www.endress.com

A smart actuator now available as an explosion-proof version

This company is highlighting its small, smart, ProFox actuator series (photo), which recently has been expanded with a new explosion-proof version — a perfect fit for those areas in water-treatment plants where methane can build up, for example. Sustainable and easy to integrate, these versatile actuators are key enablers for digital transformation in modern process automation. ProFox actuators offer high-precision automation solutions for all valve types in the lower torque and thrust ranges. They are optimized for low energy consumption and high efficiency, thus minimizing their carbon footprint. The actuators' support for fieldbus and Industrial Ethernet communication makes host-system integration flexible and easy. Embedded data logging enables advanced diagnostics and predictive maintenance. Hall C2, Stand 141/240 — *AUMA Riester GmbH & Co. KG, Müllheim, Germany*
www.auma.com

Equipment for the efficient recycling of PET

Polyethylene terephthalate (PET) is a commonly used plastic, particularly in the production of beverage bottles. However, the improper disposal of PET bottles leads to environmental pollution and the waste of valuable resources. This company's equipment addresses this challenge by enabling the efficient recycling of PET. Through advanced technologies and processes for the thermal separation of substances that are difficult to handle, the equipment effectively transforms PET waste into high-quality recycled PET (rPET). These rPET materials can then be used in the production of new PET products, reducing the need for virgin plastic and minimizing the environmental impact. The company's technology also enables the production of bioplastics, such as polylactic acid (PLA) and polyethylene furan-2,5-dicarboxylate (PEF). Hall A2, Stand 120 — *Buss-SMS-Canzler GmbH, Butzbach, Germany*
www.sms-vt.com

New high-efficiency mixers for sludge handling

The AmaProp mixers (photo, p. 47) are used for applications in handling sludge and biological wastewater treat-

ment. The electric drives are either IE5 Ultra Premium Efficiency synchronous reluctance motors or IE3 Premium Efficiency asynchronous motors with ratings from 0.85 to 20.0 kW. Unlike conventional synchronous motors, the IE5 synchronous reluctance motors are made without any magnetic materials. The shaft sealing is performed by two bi-directional mechanical seals in tandem arrangement with a liquid reservoir. The latter is filled with ecologically acceptable white oil. An oil sensor fitted at the mating ring of the mechanical seal triggers an alarm if any damage occurs to the mechanical seals. As standard, the motors are equipped with maintenance-free bearings and temperature sensors to protect the winding against overheating. They are also fitted with leakage sensors. Users can order additional sensor packages to monitor the bearing temperature or vibrations, for example. The glass-fiber-reinforced two- or three-blade epoxy-resin propellers are as lightweight as they are break-proof, with diameters ranging from 800 to 2,600 mm. Hall B1, Stand 227/326 — *KSB SE & Co. KGaA, Frankenthal, Germany*
www.ksb.com

Maintain boiler efficiency with this cleaning technology

When installed on a boiler, the stationary, automated CloudEx system ensures a safe, deep-cleaning effect, and thus a consistently high level of efficiency. The CloudEx pressure-wave cleaning system (photo) is said to revolutionize the cleaning of boilers in thermal plants and sets new standards in terms of efficiency, maintenance simplicity and reduced risks. CloudEx technology enables automated boiler cleaning using gas explosions, effectively cleaning fouled heat-exchange surfaces. By using gas explosions at low operating pressures, wear-intensive components are avoided, extending the plant's lifespan and reducing operating costs. Hall A4, Stand 415/514 — *Bang&Clean Technologies AG, Othmarsingen, Switzerland*
www.bang-clean.com

Latest generation of membranes for biotreatment plants

The newest range of this company's membrane bioreactor (MBR) technology is leaner and extendable, ensuring higher packing density and increased efficiency. The new membrane line, Bio-Cel+ Series includes Bio-Cel Easy+, M+100, M+200, L+480, L+960H, L+960V, and L+1920H (photo). The UV400 PVDF ultrafiltration membrane (photo) with narrow pore-size distribution, offers up to 20% higher average flux and 40% higher peak flux than the previous generation, is specifically developed for MBR application to deliver high clean-water permeability, excellent mechanical stability, high durability, high chemical resistance and excellent effluent quality for reuse. The UV400 membrane brings advanced features and performance enhancements within the new Bio-Cel L+ Series. Hall A2, Stand 227 — *Mann+Hummel Water & Fluid Solutions S.p.A., Fano (PU), Italy*
www.mann-hummel.com

This multiple-gas detector transfers data via Bluetooth

The portable X-am 5800 multi-gas detector (photo) simultaneously measures up to six gases, depending on the sensors installed. The newly developed Catalytic Ex-Sensor (CatEx SR) is robust and can be used for measuring flammable vapors, such as gasoline, diesel and nonane, and the gases methane, propane and hydrogen. It has an automatic full-range option available for methane, allowing for gas measurements of up to 100 vol.%. Furthermore, the sensor is particularly resistant to contamination from silicone or other harmful substances. The X-am 5800 can be used with the company's cloud-based software solution, which digitalizes asset management and facilitates live data transmission. Here, the gas detector transfers the data via Bluetooth to a smartphone, which then sends it to the cloud. With the automatic test station, Dräger X-dock, data can also be transferred to the same cloud backend without a smartphone. The X-am 5800 is approved for Ex zone 0 and has been tested in accordance with ingress protection class IP 68. Hall C1, Stand 217 — *Dräger Safety AG & Co. KGaA, Lübeck, Germany*
www.draeger.com ■

Gerald Ondrey

KSB

Bang&Clean Technologies

Mann+Hummel Water & Fluid Solutions

Dräger Safety

Access Intelligence

Access Intelligence

Access Intelligence

Tresco Consoles

The 8th annual Connected Plant Conference (May 20–22; www.connectedplantconference.com) is taking place at Lake Conroe, Tex., near Houston. Hosted by *POWER* and *Chemical Engineering* magazines, the event will bring together experts from across the chemical process and power generation industries to share practical knowledge and foster best practices in digital transformation. The event includes a comprehensive technical program, as well as an Immersive Data Arena, where users can take a hands-on approach with the latest technologies. New content tracks for 2024 include in-depth discussions on artificial intelligence (AI), cybersecurity and the digital twins that form the foundation for many internet of things (IoT) technologies. This Show Preview highlights a small number of the many advanced digital technologies that will be showcased at the Connected Plant Conference.

Streamlined control consoles improve worker focus and safety

This company designs state-of-the-art control-center consoles (photo) that put operator ergonomics at the forefront to optimize operational workflow, in both standard and high-stress operational conditions. Extended shifts often lead to operator fatigue, impacting performance and safety. These ergonomically optimized consoles are designed to alleviate fatigue through features like height-adjustable worksurfaces and articulating monitor arms, ensuring comfort and support during long hours of operation. The consoles integrate multiple monitors, pushbutton controls and more, providing operators with seamless access to data. In emergency situations, the consoles are designed with strategic equipment positioning and ergonomic layouts, facilitating quick responses and critical thinking during high-pressure situations. Also, the consoles are designed with a modular frame structure that can accommodate additional console sections and new equipment, ensuring compatibility with future upgrades. Booth 204 — *Tresco Consoles, Calgary, Alta., Canada*

www.trescoconsoles.com

Advanced asset-performance and condition-monitoring software

This company recently released EtaPRO 11, the latest version of its asset-performance and condition-monitoring software suite. EtaPRO 11 uses IoT and AI technologies, including predictive-failure diagnosis, digital-twin technology and performance monitoring, to optimize performance and support digital transformation objectives. EtaPRO allows operators to fix issues before they become equipment failures, reducing downtime and improving plant availability. The software analyzes real-time plant operational data obtained from various sources and sensors, and detects signs of anomalies that may cause problems during normal operation. Booth 307 — *EtaPRO LLC, a Toshiba Group company, Amherst, N.Y.*

www.etapro.com

Flexible control and visibility enhance this OT security platform

The MetaDefender OT Security solution has been enhanced to provide organizations with enhanced visibility and control over their operational technology (OT) environments. Industrial and OT teams require complete asset visibility without disrupting OT networks and devices. MetaDefender OT Security addresses these challenges by offering a cybersecurity solution tailored to analyze OT networks, assets and protocols, as well as manage risks to OT assets through anomaly detection, prevent insider threats, meet compliance requirements and maintain proper network architecture and segmentation. With an improved Management Console, organizations can now seamlessly oversee multiple sites and distributed networks from a centralized dashboard and leverage multi-network support, remote patch management, role-based access management and active and passive monitoring. Importantly, the integration with the company's Industrial Firewall and IPS allows organizations to move beyond traditional visibility tools to control the flow of communications. Booth 401 — *OPSWAT, Inc. Tampa, Fla.*

www.opswat.com

Mary Page Bailey

Gulf Coast
special advertising section

CHEMICAL ENGINEERING
Access Intelligence

Inside:

EFFICIENT SEPARATION FOR SAFE AND PUREST PETROCHEMICALS

In the production of petrochemicals and polymers, there is no room for compromise on safety, product purity or non-stop performance. This is why international technology group **ANDRITZ** constantly expands their product portfolio and develops new solutions together with customers – while improving existing machines and processes. ANDRITZ does this by applying their comprehensive expertise in dewatering, drying, service, and automation, as well as their ability to tailor the industry's most reliable technology brands to specific needs. As a longtime provider of separation solutions for ABS, BPA, HDPE, MELAMINE, PET, PVC, and more – and with over 1,000 machines installed – ANDRITZ has both the knowledge and equipment to ensure reliable performance for any type of application.

A BROAD PORTFOLIO THAT SOLVES SPECIFIC REQUIREMENTS

Major chemical producers as well as local refineries, contractors, and plastics processors have chosen their optimal solution from the extensive ANDRITZ portfolio, including vacuum and pressurized drum filters, filter and belt presses, decanter centrifuges, filtering centrifuges (pusher, peeler), and multiple drying/cooling systems. One standout feature is ANDRITZ's ability to offer mechanical separation and drying as one package. For a tailored approach, the ANDRITZ separation specialists can further refine the chosen solution onsite or in their own state-of-the-art test centers. This makes them capable of recommending and optimize the right solution for each process step – from solvent recovery to solidification, cooling, and more. All while reducing costs, improving efficiency, and ensuring continuous performance.

SUPERIOR SERVICE AND AUTOMATION SEAL THE DEAL

Thanks to the global network of service specialists for solid/liquid separation equipment and service centers across the globe, ANDRITZ is on hand to ensure customers always get the maximum value for their investment. The separation experts also maintain close collaboration with customers in the field to continuously optimize moisture content, particle size, and mechanical reliability. For automation and process control, the Metris addIQ control system combines all of ANDRITZ's extensive operation, troubleshooting, and start-up experience in one tailored solution, to profit from the opportunities that come with digitalization: Minimizing risks while maximizing efficiency and profit.

www.andritz.com/separation

Fluid bed dryer/cooler for PVC

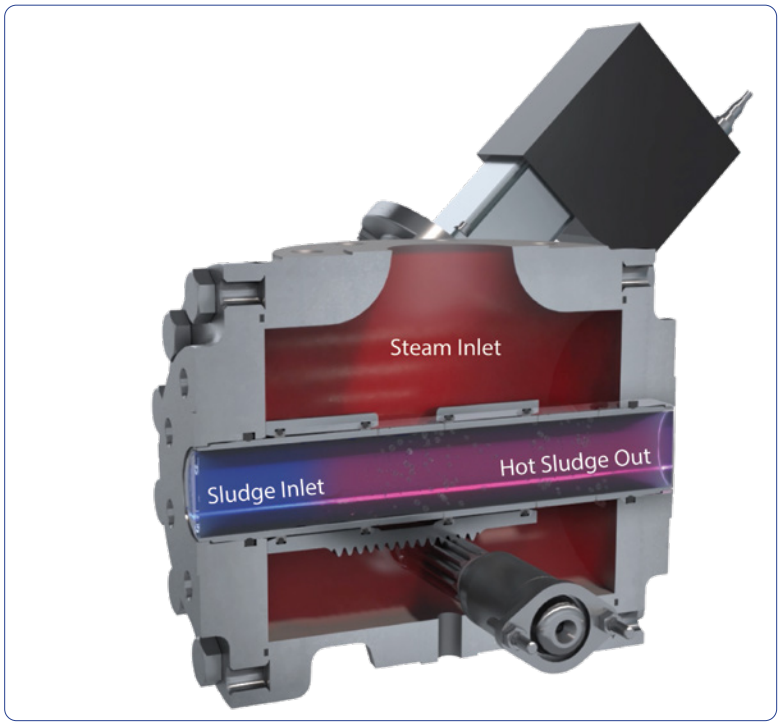
The perfect temperature — every time

Hydro-Thermal is the global leader in on-demand steam injection fluid heating, cooking, and processing systems. These heating systems are the most reliable, durable solution for heating water and slurries with instant and precise temperature control.

Hydro-Thermal's newest innovation is called the NOH, or the Non-Obstructing Heater. The NOH's straight-tube design allows for unrestricted flow, prevents pressure drop, and heats slurries without plugging or fouling. In addition, the NOH's rugged design and construction materials enable it to handle viscous slurries, particulate-filled products, abrasive/corrosive substances, stringy products, and inline water heating abilities – all are possibilities with the NOH. Compared to other heating systems, the NOH utilizes a smaller footprint, with direct installation into the existing system piping— and does not require special tools for maintenance.

Compact & Powerful: Ranging from 2" to 12" [DN50-DN300] sizes, volume capabilities reach all the way to 6,900 GPM [up to 1,567.2 m3/hr].

www.hydro-thermal.com



Make Refineries Safer with Predictive Maintenance Programs

Predictive maintenance in the oil and gas industry is not just a strategy for enhancing operational efficiency; it is a critical component for ensuring safety, preventing environmental harm, and safeguarding lives. A recent U.S. Chemical Safety Board report highlights the gravity of potential incidents, with 16 completed investigations on fire and explosion incidents and one reactive incident in oil refining from 2001 to March 2024. While seemingly rare, such incidents underscore the catastrophic consequences of equipment failure, including mechanical and electrical failures, internal erosion of piping lines, or leaks from vessels.

In this context, predictive maintenance (PdM) emerges as a vital tool. By leveraging condition monitoring, PdM allows engineers to estimate the remaining useful life (RUL) of critical equipment and classify faults before they lead to failure. The decrease in sensor prices has made PdM programs more accessible, enabling real-time data collection from multiple assets. As a result, PdM helps engineers adopt a risk-based maintenance approach to ensure the overall reliability of production equipment.

For instance, rotating systems are more prone to mechanical failure than static systems. A common mode of failure is seal failure, which may result in the discharge of hazardous materials. Some causes of seal failure include blocked suction, blocked discharge, and pump run-out. To prevent seal failure, rotating system faults should be classified promptly and accurately. Many process engineers use **MathWorks** products to develop artificial intelligence models for fault classification. These models require sufficient fault data from the equipment, which is not always feasible

or safe. Engineers also use Simulink® and Simscape™ to build physics-based models and run them in parallel to prototype multiple scenarios and outcomes rapidly. These physics-informed AI models are trained to classify outcomes by extracting condition indicators, and confusion matrix plots generated in MATLAB® help engineers validate outputs between true and predicted classifications. Dashboards and graphical interfaces built in MATLAB also help engineers deploy their findings and make data more actionable to other professionals and stakeholders involved in such industrial processes.

In essence, by harnessing MathWorks products for predictive maintenance, oil and gas and chemicals organizations can significantly mitigate the risk of potential catastrophic failures and ensure operational reliability, environmental compliance, and, most importantly, the safety of communities and workers.

https://www.mathworks.com/campaigns/offers/predictive-maintenance-oil-and-gas.html

GEA Jet Compressors and Ejectors for the Reliable Production of Green Hydrogen

Harnessing clean hydrogen means significantly contributing to CO_2 emissions reduction and fostering the energy transition in the most diverse sectors.

Green hydrogen is produced through the electrolysis of water using renewable sources of electricity. Throughout the production process, the purity and quality of the produced hydrogen and oxygen must be monitored to ensure it meets regulatory standards. Today, **GEA** especially-designed liquid jet gas compressors are a standard key component of said electrolysis process, working with the aqueous solution of the electrolysis cell -they are the ideal way to deal with hydrogen's explosivity, combustion risk and explosions of pure oxygen (as opposed to mechanical compressors or ventilators) and offer the possibility to constantly measure the gas quality and composition.

Other applications of the GEA liquid jet gas compressors are:

- Phase analysis (H_2 and O_2) in green hydrogen production.
- Hydrogenation processes (compression and solvation/reaction of the gas in one step).
- Biogas CO_2 mixtures and loop-reactors (compression and solvation/reaction of the gas in one step).

On the other hand, GEA gas ejectors are applicable within:

- Fuel cells.
- Green hydrogen ammonia mixing and compression in one step.
- H_2 natural gas mixing and compression in one step.
- H_2 syngas mixing and compression in one step.
- Natural gas recompression with natural gas.

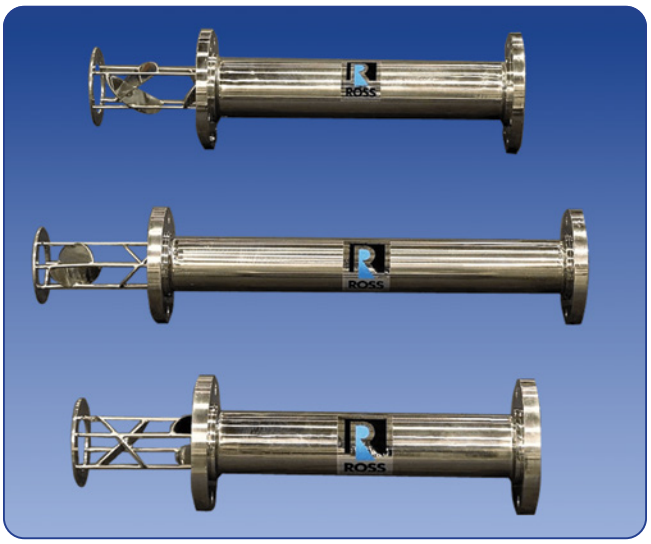
Innovation and tailored design for the processes that are shaping our future are GEA's passion.

www.gea.com

A classic mixing tool for the petroleum industry

Ross LPD Static Mixers are rugged, reliable devices that combine excellent inline mixing with minimal pressure loss

Ross Low Pressure Drop (LPD) Static Mixers are used throughout the oil and gas industry for turbulent-flow mixing applications.



Shown are removable LPD mixing elements supplied with retainer ring and flanged housing.

These heavy-duty low-maintenance devices serve in continuous operations where high performance and accuracy are required, such as on-line water determination of crude oil; dosing of various additives into gasoline; blending different kinds of fuel oils; gas-gas blending; and pipeline reactions, among others.

Static mixers have no moving parts and the energy for mixing is available in the form of pressure. Pressure loss – a natural consequence of static mixing – sometimes becomes the deciding factor in mixer selection. The LPD Static Mixer remains a classic choice for many inline blending requirements due to its simple and durable design capable of uniform mixing with little pressure loss. The mixer elements consist of semi-elliptical plates carefully positioned in series to split and rotate the product 90 deg. in alternating clockwise and counterclockwise directions.

LPD mixers in diameters from 1 in. through 2.5 in. are welded to a central rod, while larger elements are welded to four outside support rods for maximum rigidity and stability. Units as large as 48 in. diameter can be supplied as stand-alone mixer elements or as modules complete with a mixer housing and injection ports.

Established in 1842, Ross is one of the oldest and largest mixing equipment companies in the world. Ross mixing, blending, drying and dispersion equipment is used throughout many industries in the manufacture of foods, adhesives, electronics, coatings, cosmetics, pharmaceuticals, plastics and composites.

www.staticmixers.com

On-site calibration services

Maximizing process uptime while reducing risks and safeguarding compliancy

Endress+Hauser

A flowmeter that is not measuring properly can cause many problems. For example, in a custody-transfer application, even the smallest error can cost an operator millions of dollars a year. And though calibration may not be the biggest or most important task on the to-do list of a chemical plant, it can have a big effect throughout the plant. Outsourced to experts, calibration positively affects production, compliance and the risk of quality or safety deviations.

Flowmeters are often removed from systems for the purpose of calibration and sent to a calibration laboratory. The commonly held belief is that the necessary calibration accuracy can be guaranteed only under laboratory conditions. However, this is only partially true. Flowmeters and many other measuring devices can also be calibrated directly on-site. There are several advantages to this:

- Plant availability improves as the device is calibrated nearline or inline.
- Sources of error can be detected and eliminated on-site, while the ability to achieve the same result in a calibration lab is limited. Calibration technicians on-site can detect errors during installation and identify blockages or contamination in the pipes directly in the system.
- Cost savings increase due to the speed of completion, reduced downtime and the elimination of an inventory of replacement parts.
- There is no need to disassemble and ship contaminated devices, contact with hazardous substances can be reduced, and costly decontamination can be avoided.

Calibration requires time. Ideally, calibration runs are part of scheduled downtime, so manufacturing is not affected. However, experience shows that windows for scheduled downtime get shorter and shorter. Usually, instrumentation is handled last. This is why calibration should always be performed in a time-optimized manner. On-site calibration reduces coordination efforts, eliminating the need to remove and transport an instrument to a calibration facility. While it might take days or weeks for a device to return from a calibration lab, an on-site calibration can be performed within hours.

With in-depth application, metrology and measurement expertise, certified operators, and traceable documentation, **Endress+Hauser** can maximize the potential of on-site calibration without compromising safety or compliancy.

https://eh.digital/onsite-calibration

The Role of Ceramic Measuring Cells in Pressure Measurement

Pressure measurement is one of the most common means of process control. The technology is versatile because it can measure level, density and interface, and users can choose a measuring cell material that best suits their processes.

Ceramic is emerging as a cell material compared to the more popular metal to measure corrosive liquids in challenging applications. **VEGA** pressure transmitters eliminate moisture sensitivity and temperature shock susceptibility. Developed in accordance with SIL standards, the VEGABAR 80 family surpasses most, if not all sensors currently found on the market, in terms of several features.

Recently, the biggest leaps in technology have been experienced by the ceramic measuring cell 'CERTEC' – the core technology of VEGA's pressure sensors. Only a few suppliers have ceramic-capacitive cells in their portfolio, and even fewer have the know-how to manufacture these.

In principle, both metal and ceramic can be used in a majority of applications. However, in many cases, ceramic is the better technology because it is more stable, robust, and durable.

With an overload resistance factor of up to 200, CERTEC surpasses other ceramic transmitters, ensuring reliability even in demanding conditions.

- **Extended Temperature Range:** CERTEC withstands temperatures up to 266°F (130°C), eliminating the need for specialized high-temperature versions for sterilization processes.
- **Expanded Measuring Range:** Ceramic measuring cells offer a measuring range of only 3 psi or 25 mbar, without electronic turndown, with an upper measuring of 14.5 psi (100 mbar).
- **Front-Flush Mounting:** CERTEC is the only ceramic measuring cell on the market allowing front-flush mounting, ideal for abrasive applications.
- **Second Line of Defense:** Critical for hazardous applications like phosgene handling, this feature prevents leakage into terminal compartments.

The VEGABAR 80 series offers a universal housing, electronics, and adjustment concept for all measurement methods. It facilitates customers' day-to-day work throughout the entire lifecycle of an instrument for pressure and level.

VEGA

For more information visit: **www.vega.com.**

If you can't eliminate your CO_2 emissions, capture them!

Carbon capture, utilization and storage (CCUS) has a critically important role to play on the path to net zero. For those emissions that are impossible to completely eradicate through carbon reduction strategies, for example from industrial activities like hydrocarbon processing, **Sulzer**'s CCUS solutions can help to capture and transform the remaining emissions into valuable resources to be sold and used in a variety of sectors, thereby enabling circularity and the decarbonization of heavy industries.

The most compelling and cost-effective way to deal with carbon emissions once captured is to utilize at least a part of them as a resource, in line with circularity principles. For example, captured CO_2 can be used to produce sustainable aviation fuels – an energy application that is particularly hard to decarbonize. Carbon is also the key building block of chemicals and polymers and widely used in the healthcare sector and the food industry. Moreover, it can support the production of carbon-negative concrete by crystallizing the carbon and permanently storing it within concrete.

This creates additional incentives and opportunities for emissions-heavy businesses to capture their carbon – not only does society benefit, but there are also real financial gains to be realized by reusing the captured CO_2 as a valuable resource. Hydrocarbon processing facilities can potentially become independent, closed-loop facilities, where the carbon generated by the main plant's activities is then reintroduced into the system as feedstock to produce chemicals, materials or fuels.

The critical component in carbon capture units is the separation technology that is used to separate the CO_2 from the other flue gases produced during industrial processing. To deliver optimum performance in these separation columns, Sulzer has developed its proprietary MellapakCC™ structured packing, which was designed specifically for carbon capture applications. More precisely, this cost-effective technology increases efficiency by 20% when compared to conventional structured packing, while enabling the capture of the vast majority of carbon emissions.

For more information:
www.sulzer.com/chemtech

End-to-End Turnaround Planning Plus Global Service Approach Reduces Costs and Outages

What should you expect from a turnaround or retrofit project? A provider strategically positioned for fast customer response anywhere in the world, with field experience and technical expertise to get the job done right. **Zeeco**'s turnaround services mean you have a single point of on-site contact for all your fired equipment during a planned shutdown. If you need to retrofit burners or reduce emissions, trust Zeeco for an end-to-end gas or hydrogen-firing burner retrofit solution.

Our streamlined system ensures that all planning and project execution is managed quickly and efficiently through a single point of contact. From before your system is engineered to years after its commissioning, Zeeco's Global Field Services group backs you up with the technical services and field expertise to optimize equipment performance and enhance daily operation. Some of the services we offer include:

- Start-up & Commissioning
- Training
- Maintenance Agreements
- Combustion and Equipment Surveys
- Unmanned Aerial (Drone) Inspection
- Turnkey Power Solutions and Services
- Flare Tip Replacements
- Vapor Control Service and Maintenance

Zeeco can supply parts for all Original Equipment Manufacturers' (OEM) combustion equipment with competitive pricing and rapid delivery. Our engineers are industry experts with a customer-first mentality. With Zeeco combustion specialists on-site, rest assured that your equipment will be installed and commissioned correctly – avoiding costly mistakes that affect future performance.

If you face a full-scale emergency, our Disaster Response Team can immediately deploy drone inspections, equipment assessments, or heroic repair and rental solutions to return companies to service quickly. Whether your maintenance need is simple or an emergency, renting the right combustion equipment can be frustrating. ZEECO combustion rentals span the scope and capacity to keep any facility's essential operations online during planned and emergency flare outages. Our rental flare systems are supported entirely by ZEECO turnkey combustion services. They can help operators keep specific processes online – eliminating the need to fully de-inventory plants and shortening turnarounds. ZEECO rental equipment includes flare systems, flare monitoring and control systems, thermal oxidizers, and vapor combustors. Our aftermarket team delivers the same attention to detail, engineered expertise, and on-time, on-spec performance – whether you have ZEECO equipment or not. From turnarounds through retrofits and rental equipment, Zeeco's project management and engineering expertise consistently deliver the outcomes our customers demand. For more information, contact sales@zeeco.com or call 918 258 8551. **www.zeeco.com**

Boiler Solutions for the Petrochemical and Processing Industries

HRST specializes in technical services for Waste Heat Boilers, Process Gas Boilers, OTSGs, HRSGs and Package Boilers for the power industries.

HRST combines 25 years of experience from field inspection, engineering, and design to analyze and solve boiler related problems. **HRST**'s engineering and design teams provide innovative analysis and solutions, and the technical field advisors provide expert guidance on repair work and installation.

INSPECT.

HRST offers several inspection services including pre-turnaround with thermal survey, visual Inspections, online inspections, and advanced inspections with NDE. Visit HRST's website to learn more about FAC UT Monitoring, CPS Inspections, Drone Inspections, and NDE Services.

ANALYZE.

HRST's thermal analysis software can help any facility's team better understand boiler performance for process upgrades, monitoring service life, and failure analysis. HRST offers process and performance upgrades like de-bottlenecking studies and thermal performance assessments. HRST understands how modifications can affect system operation and determine component operating limits with their proprietary modeling software, HRST Performance Pro. HRST is also able to study and quantify thermal effects on boiler operation and performance.

SOLVE.

HRST takes experience from inspections and problem analysis to develop innovative design solutions. These solutions often become products for clients, including pressure parts, burner viewports, piping penetration seals, complete liner systems and system re-designs. HRST also provides technical field services to support projects. HRST expert guidance from Technical Field Services can offer turnkey solutions, repairs, vendor surveillance, technical advisors with installation, and quality assurance. HRST provides training on-site or off, with HRSG Academy (twice per year), on-site training, and on-demand remote training.

Occasionally clients have an emergency need for HRST's engineering or technical advisory services due to unforeseen failures leading to forced outages. HRST deploys an expert on-site to identify the problem, provide a solution, and oversee repairs, ensuring that the facility is back up and running as soon as possible.

Globally, HRST engineers, technicians, designers, field advisors, and project managers are committed to helping clients avoid and solve costly boiler problems. HRST is represented throughout the United States with regional offices in California, Colorado, Florida, Maine, Maryland, Minnesota, and Texas. HRST has international offices in Vietnam and Mexico and is a registered business entity in Australia.

www.hrstinc.com/process-boilers

HOT PRODUCTS

www.rembe.de

Safe and sustainable – the next generation of flameless explosion venting

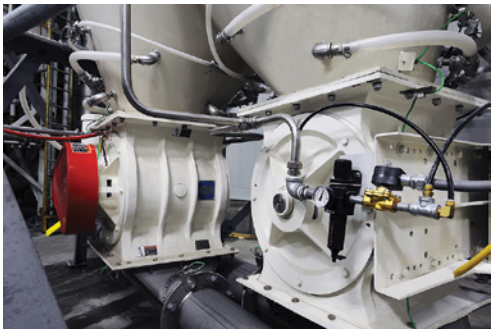
As the inventor of flameless explosion venting, REMBE is once again challenging the status quo with the new Q-Box R3leaf, the world's first sustainable device for flameless explosion venting.

After years of systematic development, numerous tests and successful approval tests, REMBE is convinced that it has contributed to more than just an improvement in flameless explosion venting technology. Instead, the aim is to set a good example and send a clear signal that everyone can reduce the carbon footprint in our industry.

During development of the Q-Box R3leaf the focus was on sustainability and the central question: Where can the status quo be further challenged?

The development of the Q-Box R3leaf expands REMBE's line of flameless explosion venting devices with a product optimised in terms of both effectiveness and sustainability.

For details visit adlinks.chemengonline.com/86463-20



schenckprocess

Schenck Process Food and Performance Materials
Kansas City, MO
816-891-9300
americas@schenckprocess.com
www.schenckprocessfpm.com

Universal Airlock for Pneumatic Conveying Systems

With tens of thousands of installations throughout the world, the Schenck Process Food and Performance Materials (FPM) Multi-Duty (MD) airlock is a highly universal airlock used to meter dry bulk materials under feeding devices, such as bins, hoppers, mixers, screw conveyors and sifters.

Providing rugged service, the MD Airlock is suitable for use in dilute phase vacuum, pressure or combination vacuum/pressure pneumatic conveying systems. Low mounting height is ideal for space restricted applications. With a low profile and a wide flange width, the MD Airlock is able to match drill hole patterns of many competitor's valves for easy replacement. A domed hopper cover and open bottom frame speeds and optimizes draining during and after wash-down cycles. Smooth, crevice-free product contact surfaces at 32 micro inch or better help prevent the formation of bacteria.

The MD Airlock has a cast housing and endplates with a square flange. The rotor and housing are precision machined to obtain a high degree of accuracy and close tolerances. Close tolerances hold the differential pressure across the valve to reduce air leakage. Reducing leakage saves supply gas, reduces spikes in velocity and stabilizes the system.

For details visit adlinks.chemengonline.com/86463-21

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Classified Index May 2024

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Economic Indicators

2022 2023 2024

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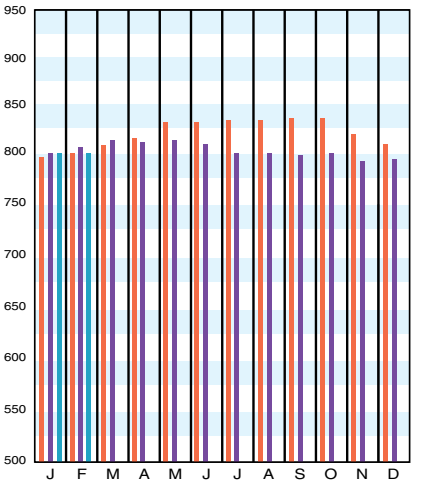
CHEMICAL ENGINEERING PLANT COST INDEX® (CEPCI)

(1957–59 = 100)	Feb. '24 Prelim.	Jan. '24 Final	Feb. '23 Final
CE Index	800.3	795.4	798.0
Equipment	1,005.7	998.1	1,008.2
Heat exchangers & tanks	811.7	805.0	820.2
Process machinery	1,033.6	1,027.3	1,031.4
Pipe, valves & fittings	1,350.3	1343.3	1,403.4
Process instruments	568.1	567.5	565.1
Pumps & compressors	1,518.9	1517.3	1,391.5
Electrical equipment	812.2	810.8	794.7
Structural supports & misc.	1,130.5	1106.6	1,120.8
Construction labor	372.4	374.9	358.6
Buildings	821.5	813.8	801.5
Engineering & supervision	314.8	315.3	311.3

Annual Index:
2016 = 541.7
2017 = 567.5
2018 = 603.1
2019 = 607.5
2020 = 596.2
2021 = 708.8
2022 = 816.0
2023 = 797.9

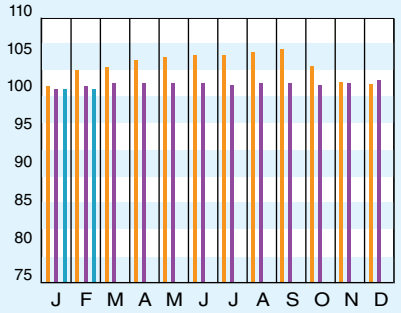


Starting in April 2007, several data series for labor and compressors were converted to accommodate series IDs discontinued by the U.S. Bureau of Labor Statistics (BLS). Starting in March 2018, the data series for chemical industry special machinery was replaced because the series was discontinued by BLS (see *Chem. Eng.*, April 2018, p. 76–77.)

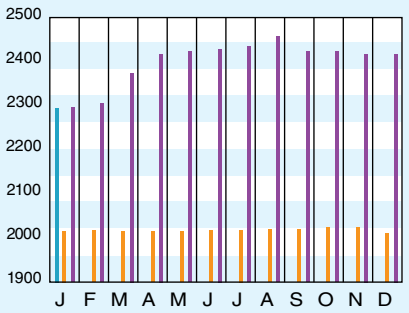
CURRENT BUSINESS INDICATORS

	LATEST	PREVIOUS	YEAR AGO
CPI output index (2017 = 100)	Feb. '24 = 98.9	Jan. '24 = 98.1	Dec. '23 = 99.8	Feb. '23 = 100.0
CPI value of output, $ billions	Jan. '24 = 2,341.1	Dec. '23 = 2,378.9	Nov. '23 = 2,397.2	Jan. '23 = 2,452.9
CPI operating rate, %	Feb. '24 = 78.2	Jan. '24 = 77.6	Dec. '23 = 79.2	Feb. '23 = 80.0
Producer prices, industrial chemicals (1982 = 100)	Feb. '24 = 295.7	Dec. '23 = 291.3	Dec. '23 = 302.2	Feb. '23 = 336.4
Industrial Production in Manufacturing (2017 =100)*	Feb. '24 = 99.2	Jan. '24 = 98.4	Dec. '23 = 99.5	Feb. '23 = 99.9
Hourly earnings index, chemical & allied products (1992 = 100)	Jan. '24 = 231.0	Dec. '23 = 230.6	Nov. '23 = 228.9	Jan. '23 = 211.6
Productivity index, chemicals & allied products (1992 = 100)	Feb. '24 = 94.2	Jan. '24 = 93.1	Dec. '23 = 94.1	Feb. '23 = 94.0

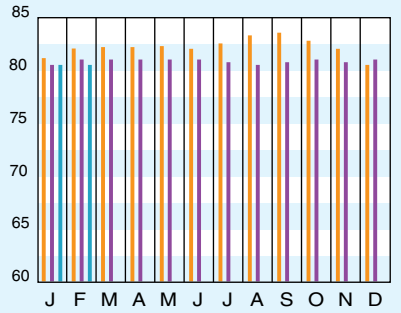
CPI OUTPUT INDEX (2017 = 100)†



CPI OUTPUT VALUE ($ BILLIONS)



CPI OPERATING RATE (%)



*Due to discontinuance, the Index of Industrial Activity has been replaced by the Industrial Production in Manufacturing index from the U.S. Federal Reserve Board.
†For the current month's CPI output index values, the base year was changed from 2012 to 2017
Current business indicators provided by Global Insight, Inc., Lexington, Mass.

CURRENT TRENDS

The preliminary value for the *CE* Plant Cost Index (CEPCI; top) for February 2024 (most recent available) rose compared to the previous month's value, continuing a string of increases over the past three months. For February, the increase in the overall CEPCI was driven by gains in the Equipment and Buildings subindices, which offset smaller decreases in both the Construction Labor and Engineering & Supervision subindices. The current CEPCI value now sits at 0.3% higher than the corresponding value from February 2023. The higher year-upon-year value for this month marks the first time in a year that the current CEPCI value is above the corresponding year-ago value. Meanwhile, Current Business Indicators show a rise in the CPI output index.